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# EUTROPHICATION OF SURFACE WATERS - LAKE TAHOE: PILOT POND AND FIELD STUDIES

Lake Tahoe Area Council
South Lake Tahoe, California

May 1970

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# EUTROPHICATION OF SURFACE WATERS—LAKE TAHOE

## PILOT POND AND FIELD STUDIES

Third Progress Report
(FWQA Grant No. 16010 DSW)
May 1970

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**Lake Tahoe Area Council**
**South Lake Tahoe**
**California**

119

# THIRD PROGRESS REPORT

# EUTROPHICATION OF SURFACE WATERS - LAKE TAHOE PILOT POND AND FIELD STUDIES

by

LAKE TAHOE AREA COUNCIL

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FEDERAL WATER QUALITY ADMINISTRATION
U. S. Department of the Interior
FWQA Grant No. 16010 DSW
Demonstration Project - Eutrophication
of Surface Waters

May 1970

Lake Tahoe Area Council
South Lake Tahoe, California 95705

## FWQA Review Notice

This report has been reviewed by the Federal Water Quality Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Quality Administration, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# PREFACE

This is the third in a series of reports on the progress of FWQA Demonstration Grant No. 16010 DSW (previously WPD - 48) to the Lake Tahoe Area Council for the purpose of identifying and evaluating the various sources of algal growth stimulants which may lead to the eutrophication of surface waters - with special reference to their implications to Lake Tahoe. The nature and scope of the report are presented in detail in Chapter I; and the progress of the study documented and evaluated in subsequent chapters.

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# CHAPTER I

# INTRODUCTION

## NEED FOR STUDY

Need for the study herein reported derives both from the factors which lead to excess nutrients in surface waters of the United States, and the resultant overproduction of algae, and from the unique nature of Lake Tahoe which sets it apart from other bodies of water.

In the general case of surface waters, the nutrient-rich condition which characterizes eutrophic water is not always the result of man's activities. Occasionally lakes, ponds, and streams even under wilderness conditions receive sufficient nutrients from plant and animal residues to support a rich flora and fauna.

In the more common situation, to which the study is directed, nutrient concentrations are initially low enough that the water is well suited to such high levels of use as domestic water supply, while at the same time supporting a good fish fauna and the food chain on which it depends. Here the source of nutrients is degradation of rocks and the decay of organic matter washed in from land surfaces or blown in from bordering vegetation and, generally, recycled within the water itself. Such a natural equilibrium is disturbed when man diverts water and returns it with the burden of biochemically unstable organic wastes from human life processes. A critical situation develops when the number and concentration of people, or when a combination of human numbers, industrial activity, land fertilization, concentration of livestock, disturbance of natural cover, and so on, produces nutrients at a level which overfertilizes natural waters. Such highly eutrophic waters are objectionable to man because the excess aquatic growth that develops in such an environment renders them aesthetically unattractive or otherwise unsuited to beneficial use.

Throughout the United States the percentage of the water resource which has eutrophic characteristics has grown rapidly in recent years. Green scums, hairlike filaments on shoreline rocks, and shallows clogged with weeds have increasingly appeared in waters formerly free of such nuisance. Algal blooms have increased the cost of obtaining pure water and have aroused public indignation. Regulatory agencies have increasingly set water quality standards at levels intended to preclude the discharge of growth stimulating factors into receiving waters.

The specific situation in which there is a need to evaluate the applicability to Lake Tahoe of measures generally suited to the control of eutrophication, exists because the lake is unlike anything generally found in the world. Its water is exceptionally low in phosphorus, nitrogen, and other growth stimulating factors. It is deep, well mixed, and water temperatures are low due to altitude and the snowmelt which feeds it. The lake occupies a large percentage of the Lake Tahoe Basin; consequently water export must be limited if the integrity of the lake is to be maintained. Finally, no one knows the exact degree to which nutrient enrichment of the lake is reduced by export of sewage effluents; the measures necessary to permit retention of waste waters in the basin; or the precise percentage increase in natural fertilization of the lake resulting from human activities. Moreover, the lake is under extremely heavy population pressure with attendant motivation to develop shoreline facilities and a regional economy along accustomed patterns in which unique environmental aspects are not so important a factor.

Clearly there is a need for study of the origin and nature of growth stimulating materials both in surface waters in general and in Lake Tahoe in particular. The specific details of this need are presented in the Second Progress Report [1] from which the following paragraphs are restated.

The obvious source of nutrients is effluent discharged as municipal, agricultural, and industrial waste water. First attention to such wastes, however, was logically directed in the past to their oxygen demanding properties (BOD) and to their deleterious effect on aquatic life and on the aesthetic quality of water which various other beneficial uses require. Consequently, the art of sewage treatment developed around biostabilization of degradable organic matter and until quite recently treatment processes have become progressively more sophisticated principally in their ability to oxidize organic matter. Unfortunately, the oxidized forms of nitrogen and phosphorus are in themselves significant growth stimulants, and their presence in waste water, along with biosynthesized vitamins, amino acids, trace elements, and other growth factors found in biologically treated wastes, raises serious questions as to the suitability of conventional waste treatment for control of nutrients influencing eutrophication.

In response to these questions the concept of nutrient removal from sewage effluent has recently had widespread appeal in water quality management. Because a few of the blue-green algae, one of the most important representatives of nuisance algal blooms, can fix nitrogen from the atmosphere, and because of the increasing quantities of nitrogen in rain, it is widely suggested that phosphorus is the critical nutrient and should be the first to be removed from sewage effluents. Nitrogen and phosphorus removal has been advocated and is already being practiced in the South Lake Tahoe area.

There is, therefore, a need to determine several factors in relation to sewage effluents, including:

1. The concentrations at which nitrogen and phosphorus will trigger or support substantial algal growth.
2. The algal growth stimulating effect of sewage from which nitrogen and phosphorus has been partially removed.
3. The ability of practical nutrient removal processes to reduce nitrogen and phosphorus to levels below that critical to algal growth.

The assumption that domestic and industrial waste water effluents are the principal source of nutrients is not necessarily valid. In many instances in the lake country of the middle west fertilizing of agricultural land and animal manure disposal practices are significant factors in eutrophication of lakes. Consequently there is a need to evaluate the relative role of sewage effluents and other sources of nutrients in the stimulation of algal growth in surface waters.

With specific reference to Lake Tahoe, where the basin is forested, population is increasing, and land use encourages erosion and follows the same pattern as other urban developments, it is particularly important to evaluate the various sources of nutrients. Export of sewage effluents from the basin is well advanced both in practice and in planning for the future. Approximately 50 percent of the sewage generated within the Basin is now being exported from the watershed. Collection and transport systems to export the remainder are planned for completion in the early 1970's. Here the need for study takes on other aspects:

1. The residual ability of tertiary (nutrient stripped) sewage effluents to stimulate algal growth.
2. The ultimate fate of nutrients removed from sewage in the Tahoe Basin.
3. The overall amount of nutrients reaching Lake Tahoe annually from the normal processes of nature in the basin (including precipitation).

4. The effect of man's near-shore and shoreline modifications and activities on the biology and natural beauty.

5. The significance of the findings of laboratory and pond assays in terms of Lake Tahoe water under lake conditions.

In relation to the foregoing needs it has been suggested that it would be particularly ironical and tragic if the nitrogen stripped from sewage found its way into the lake via rainfall and phosphate via pickup from landfill, while the purified water from which they were removed was needlessly exported from the basin. Although it has not been shown that such is the case, the speculation underscores the need for studies of the type herein reported.

Because shoreline development and construction may influence both the input of nutrients and the way the lake responds to them, there is a need to interpret the results of assays in relation to:

1. Development of flood plains, meadows, and marshlands.

2. Construction of marinas, lagoons, and breakwaters.

3. General construction practices throughout the watershed.

## OBJECTIVES OF STUDY

The general objectives of the study are implicit in the need outlined in the preceding section. Specific objectives include:

1. To determine, by the most effective laboratory bioassay techniques available, whether there is present in effluents from waste water treatment processes, or in surface wash or groundwater seepage from inhabited or uninhabited areas, materials capable of stimulating algal growth in surface waters; and at what concentration they may be significant.

2. To demonstrate by studies on artificial ponds the applicability to Lake Tahoe of the results of laboratory assays or possible inputs to the lake.

3. To evaluate the danger to Lake Tahoe of man's waste effluents and land practices in the basin, on the basis of results of studies in pilot-scale experimental ponds and a survey of the various nutrient sources within the basin.

4. To compare the growth stimilating characteristics of tertiary effluent in Lake Tahoe water with that of the same effluent when ponded in Indian Creek Reservoir. (Supplemented by Demonstration Grant No. 16010 DNY.)

5. To prepare an authoritative document (Final Report) on eutrophication of surface waters based on the findings of the study throughout its total grant period and current knowledge of the problem at the time of reporting.

## SCOPE OF REPORT

The report herein presented is concerned primarily with the second, third, and fourth objectives. Relative to objective No. 2 (above) the report presents the findings of pilot pond assays of secondary and tertiary sewage effluents in Lake Tahoe water at concentrations of one percent and two percent; and of Lake Tahoe water with nitrogen and phosphorus added as chemicals in amounts equivalent to that found to be present in the sewage effluents.

Pursuant to objective No. 3 flask bioassays of the effluent from the pilot ponds, together with the data on algal growth stimulated by chemical nutrients, form the basis for judging the effect of impoundments or marinas on eutrophication of Lake Tahoe.

Concerning the fourth objective the report draws upon results of the pilot pond assays and of field and laboratory observations of Indian Creek Reservoir to compare the probable behavior of Lake Tahoe when fertilized with highly treated effluent with that of an impoundment of tertiary effluent with a minimum of dilution with surface water. To avoid unnecessary repetition of material and cost of publication the principal analysis of Indian Creek Reservoir per se appears in a companion report [2] entitled: "Eutrophication of Surface Waters – Lake Tahoe (Indian Creek Reservoir), First Progress Report," dated May 1970.

## ORGANIZATION OF STUDY

The study was made possible by a Demonstration Grant No. 16010 DSW (initially No. WPD – 48) to the Lake Tahoe Area Council by the Federal Water Quality Administration of the U. S. Department of the Interior. Financial accountability for the project was maintained by the Council. Technical direction of the study was provided by the Lake Tahoe Area Council Board of Consultants consisting of Professor P. H. McGauhey, Dr. G. A. Rohlich, and Dr. Erman A. Pearson. In planning the experimental work and in evaluating the results the Board was assisted by Dr. Arthur D. Hasler, University of Wisconsin; Dr. James B. Lackey, Consulting Biologist, of Melrose, Florida; and Dr. E. J. Middlebrooks, University of California, Berkeley. Experimental and data processing were under the direction of a resident staff headed by Dr. Gordon L. Dugan, Project Engineer-Biologist, and Dr. Donald B. Porcella, Project Limnologist. Mrs. Florence Kupka and Mr. Peter Cowan were responsible for laboratory analytical work, pilot plant operation, and field studies; with the assistance of Mr. Jack Archambault and Mrs. Nancy Deliantoni. Cooperating with the Lake Tahoe Area Council and its consultants in planning the demonstration program, assembling data, and developing facilities were such public agencies as: University of California; California Regional Water Quality Control Board No. 6; California State Department of Water Resources; California State Department of Fish and Game; Federal Water Pollution Control Administration; California State Department of Public Health; Nevada State Department of Public Health; Douglas County Health Department; Placer County Health Department; South Tahoe Public Utilities District; and U. S. Public Health Service, Region IX. Mr. Thomas E. Maloney of the FWQA Pacific Northwest Water Laboratory served as Project Officer for the sponsoring agency; and Mr. William Johnson of the Alameda, California office of FWQA served in a similar capacity at the regional level.

Laboratory facilities and outdoor space for pilot ponds were developed through the cooperation of the California Department of Fish and Game which maintains a hatchery building at the Tahoe City site utilized for the study. The U. S. Coast Guard and Placer County cooperated in the project by providing a site for a lake water pumping station and easement for a pipeline leading to the pilot ponds. Cooperation of the University of California at Davis, and of Dr. Charles Goldman of that institution, helped minimize the cost of laboratory installations and sampling of surface waters. The South Tahoe Public Utilities District cooperated in the sampling activities of the project. The California Department of Water Resources participated directly in the work in Indian Creek Reservoir, taking responsibility for the hydrological, geological, and meteorological aspects of the study.

## ACKNOWLEDGMENTS

The Lake Tahoe Area Council, its Board of Consultants, and the Demonstration Project staff acknowledge with thanks the cooperation and assistance provided by the many agencies and individuals who were helpful to the project during the past year.

# CHAPTER II

## MATERIALS AND METHODS

### INTRODUCTION

Two basic assay methods - batch and continuous culture - together with appropriate chemical and physical analyses were used to explore the potential of various constituents which may accelerate eutrophication of surface waters, or trigger eutrophication of Lake Tahoe. Batch assays were conducted in flasks and the continuous flow technique was applied in outdoor ponds. The results of laboratory assays of Lake Tahoe Water (LTW) with added nutrients were tested under conditions which simulated shoreline Lake Tahoe situations in the outdoor ponds. Samples of waste water effluents, and of natural sources of nutrient inputs to the Lake, assayed by laboratory and pond techniques were collected, treated, and analyzed as hereinafter described. The test alga used in flask assays is likewise described in this chapter, as are special apparatus and specific procedures used in flask and pond assays.

### SAMPLING AND ANALYSIS

#### Source of Samples

The various sources of samples used for assays included surface runoff from three land areas in differing stages of development, sewage effluents, and Lake Tahoe water. Ward, Incline, and Upper Truckee-Trout creeks were monitored, as in previous years [1,3], as examples of surface runoff from relatively undeveloped, newly developed, and well-established urbanized land areas, respectively. Waste water discharges chosen for assay were secondary and tertiary effluents from the treatment plant of the South Tahoe Public Utility District. Samples of water from Lake Tahoe were obtained from two sampling stations, one located in a deep portion of the lake - the other near the north shore Coast Guard Station (Tahoe City).

#### Method and Frequency of Sampling

All samples, with the exception of effluent from the continuous flow ponds, were collected in either 1/2-gallon, 1-gallon, or 5-gallon polyethylene containers. Continuous flow of Lake Tahoe water to the ponds was maintained by means of a shoreline pump and piping system located on the north shore at the U. S. Coast Guard Station. Samples of the pond effluent were collected by a laboratory technician using the "grab" method. Containers previously washed in the laboratory were rinsed with the liquid to be sampled at the time of collection. Samples were collected at regular intervals; the containers were segregated, labeled, and each reused only for collection of samples from the one specific source to which it was allocated.

#### Preparation of Samples

Preliminary preparation of samples for physical and chemical analyses varied somewhat depending on the specific method chosen for each assay. Samples selected for flask culture, including Lake Tahoe water used for dilution, were filtered through Whatman glass fiber filter pads (GF/C) and finally through HA Millipore$^{(R)}$ filters (0.45 μ pore size). They were then stored in tightly covered polyethylene containers and frozen, unless the test was to begin within five days. Due to the large quantity of water required for pond studies, sewage effluents used in the continuous flow pond assays were not filtered.

Aliquants of the samples, both the unfiltered and those passed through the previously described glass fiber and millipore filters, were analyzed chemically for a number of constituents. Samples were kept in tightly capped 2-ℓ polyethylene containers and stored in a refrigerator at temperatures approaching 0°C until all chemical determinations were completed. Glassware employed in conjunction with the assay was dry heat sterilized.

## Analytical Procedures

Chemical analyses were made according to Standard Methods [4] in determining biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, alkalinity, ammonia, chlorides, and conductivity. Methods described by Strickland and Parsons [5] were considered more suitable for iron, nitrite, nitrate, and reactive inorganic phosphorus at the low concentrations prevailing in the Tahoe samples. Similarly, procedures recommended by Jenkins [6], were found more appropriate for soluble organic phosphorus and soluble organic nitrogen. Details of individual analyses are presented in Appendix A. All laboratory chemical determinations were subjected to replicate analyses on aliquots of the same sample, as previously reported for the years 1967-1968 and 1968-1969 [1,3], to determine the precision of results attainable by the project staff by the analytical procedures used. The results showed that with the exception of organic nitrogen and total phosphorus in Lake Tahoe water, where concentrations are extremely small, the chemical analytical work is of good accuracy in terms of the coefficient of variation. A statistical analysis of the two methods of laboratory filtration (0.45 μ HA Millipore and GF/C Whatman glass fiber filter paper) indicated that there is no essential difference in the accuracy of the two methods.

The technique for measuring total suspended solids (SS) and volatile suspended solids (VSS) was patterned from a combination of the procedures outlined in Standard Methods [4]; Strickland and Parsons [5]; and Maciolek [7]. Whatman glass filters (GF/C) were used in solids separation. The filters were prepared by soaking in distilled water to wash the fibers free of salts. They were then placed in a muffle furnace for 30 minutes at 450°C to destroy any organic matter present without fusing the glass fibers. After cooling, the filters were dried in a hot air oven at 75°C and tared quickly on a Mettler semimicro balance, to avoid error due to the extremely hydroscopic nature of the dried filter. In making the solids determinations the sample was applied to the filter until the volume had passed through or until the filter was completely clogged. The volume of filtrate was noted. The filter pads with their load of suspended solids were dried overnight at 75°C and the dry weight recorded to the nearest 0.01 mg. They were then saved for further analyses by placing them in marked envelopes and stored in a refrigerator freezer. Samples in which the VSS value was desired were redried and reweighed to verify the suspended solids value. Thereafter the filters were ignited at 550°C for 2 hours, soaked with a few drops of distilled water to rehydrate the mineral matter, dried overnight at 75°C, and weighed. The difference between the SS weight and the weight after ignition was then used to determine the VSS in mg/ℓ.

In some cases it was necessary to revise the suggested methods in order to expand the scope of the analysis to encompass the wide range of nutrient concentration encountered in the various samples assayed. The procedure was to prepare two standard curves for the Beckman Model B spectrophotometer, one using a 1-cm pathway cuvette and the other a 5-cm cuvette. The range of concentration using the two pathway cells was from 1 μg/ℓ to 200 μg/ℓ. Samples in which the level of the constituent exceeded the maximum range of concentration were diluted to the concentration range of the cells by a calibrated volume of deionized water.

## FLASK ASSAY

### Procedure

The theory and rationale of the flask assays are described in detail in the two previous progress reports [1,3].

In making the assay of any nutrient source, the filtered sample was first diluted to the desired concentration with filtered Lake Tahoe water. One hundred and fifty m*l* of this solution was then placed in each of five sterile 250 m*l* Erlenmeyer flasks. Cells of a species of Selenastrum in good physiological condition were centrifuged and washed twice in Lake Tahoe water to minimize the chance of nutrient carry over from the stock culture to the test flasks. An equal volume of the suspended cells was then added to each test flask, so that the concentrations of cells in the 150 m*l* of liquid was approximately 50 cells/$mm^3$.

Loose fitting plastic beakers were inverted over the tops of the inoculated test flasks, prior to being placed in a 20°C constant temperature room and incubated on a gently moving (30 cycles/min) shaker table for a period of five days. Illumination of approximately 550 ft-c (5920 lux) intensity was provided by four 30 watt G. E. fluorescent lamps, No. F40-CW, Coolwhite, four feet in length.

The cell concentration in the test flasks were determined by cell counts at the end of one, three, and five days during the five week period of incubation. After the final counts were completed, suspended solids and pH measurements were made on a composite of the liquid in the five replicate flasks.

### Test Organism

The alga Selenastrum gracile (Reinsch) was originally selected and utilized as a test organism for assays on the basis of consideration of characteristic of an ideal test organism and of favorable results reported by Skulberg [8] with the same genus. It has the disadvantage of producing large cells under rich nutrient conditions. In addition, newly formed cells tend to remain attached; but because they rarely exceed four in a group, cells are easily distinguished by "hand" counting with a microscope. These limitations were considered minor for the conditions prevailing at Tahoe when the hand procedure was used. However, in July 1969 a Model B "Coulter" counter was purchased to improve the efficiency and accuracy of cell counting. The Coulter counter functions on the principle that as each particle passes through an orifice it displaces its own volume of diluent within the orifice and thus momentarily changes the resistance value between the electrodes positioned on each side of the orifice. A cell count is recorded each time the resistance is changed. Thus, the attached newly formed S. gracile cells would be counted as a single cell instead of the multiple number they represent. For this reason the closely related organism Selenastrum capricornutum which has the same approximate advantages as S. gracile, but does not tend to "clump," was substituted for Coulter counter operations.

The basic cultures of the two Selenastrum species were maintained at a constant growth rate by the continuous culture method ($\theta = 5$ days) using a nutrient solution of 10 percent Skulberg's medium (Appendix A), which is specifically designed for culturing Selenastrum. The purity of the Selenastrum species was checked periodically by microscopic examination and contamination with other organisms was normally nonexistent. On one occasion a contamination of the basic culture with a "Chlorella type" organism developed between two successive microscopic checks. Consequently, the purity of the basic culture used in the assays for a period of approximately six weeks is in question.

## Counting Procedures

As noted in the previous section (Test Organism) two basic methods were used to count the alga cells; the hand counting method up to July 1969 and the Coulter counter method thereafter.

The hand counting procedure was initiated by removing a 10 mℓ aliquot from each flask after a incubation time of one, three, and the final five days and centrifuging the aliquot for 10-15 min at 2000 rpm (approximately 800 times gravity). After centrifugation, 8-9 mℓ of the supernatant were removed with a Pasteur pipette and the pellet of cells resuspended in the remaining liquid medium. A drop of the suspension was then put on a Spencer Bright-Line hemocytometer for counting under the microscope. Duplicate counts were made for each flask and five replicates were performed for each concentration; thus a total of 30 counts were made for each concentration of sample tested. The duplicate counts for each flask were averaged, and the resulting values were then averaged to obtain a mean count for the five replicates constituting the assay.

The method used in the Coulter counter technique involved removing a 10 mℓ aliquot from each flask. The aliquot is then diluted with a saline solution so that the final concentration is from a maximum of 50 percent to the concentration that will provide a final count of less than 10,000 particles (counting capacity of the Coulter counter) for a 0.5 mℓ diluted sample. The maximum time required for each count is 13 sec. As was done in the hand count method a mean value was obtained for the five replicates.

## Reliability, Sensitivity, and Precision of Cell Counting

Accurate cell counting techniques are imperative for meaningful kinetic studies of algal growth. A comparison of the results of the conventional hand counting technique versus the Coulter counter for the same samples is shown in Appendix A. The results of the hand counting technique, varies somewhat with the magnification used, but mainly with the ability of the individual doing the counting to judge representative cell concentration areas, superimposed cells, attached cells, etc. The Coulter counter, however, when in proper operating order, records each time a particle passes between the two electrodes. A coincidence correction coefficient is multiplied by the number of particles recorded by the Coulter counter, thereby, providing a statistical correction for the possibility of superimposed cells passing between the electrodes at the same time. Thus it is obvious that the Coulter counter should provide a much higher degree of sensitivity and reliability as well as the added benefit of a considerable time saving over the hand counting technique. The reliability of the Coulter counter was emphasized when the same sample was introduced to the Coulter counter several times in succession and the difference in the numerical results were found to be insignificant.

## POND ASSAY

## Physical Feature of the Pond System

The ponds consist of eight fiberglass-coated wooden tanks each 20 ft long, 4 ft wide, and 4 ft deep, with a water depth of approximately 3.5 ft and a capacity of about 7930-ℓ (2100 gal). The ponds were installed on a wooden platform adjacent to the south wall of the Fish and Game hatchery building, which housed the laboratory, with the long axis on the meridian. The general layout of the installation is shown schematically in Figure 2-1. At the north end of each pond a weather-tight, ventilated cabinet was constructed to house the nutrient sample containers, feed pumps, electrical controls and outlet boxes. A Jaccuzi Whirlpool submersible pump was installed in each pond and operated continuously during assay experiments to keep the pond moderately well mixed. The volume of water in the pond was maintained constant by a 1-1/2 in., galvanized iron riser standpipe threaded into an upside down floor flange built into

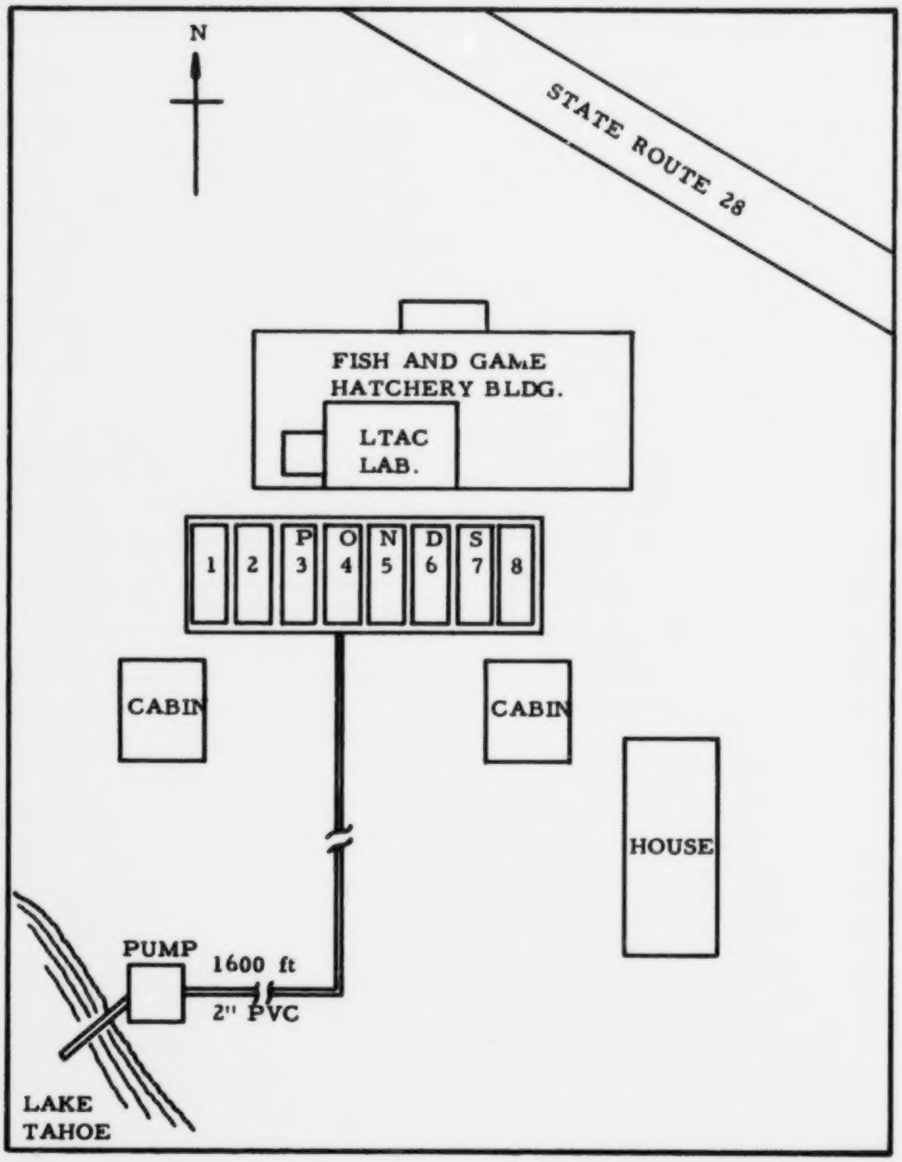
N
STATE ROUTE 28
FISH AND GAME
HATCHERY BLDG.
LTAC
LAB.
P
O
N
D
S
1
2
3
4
5
6
7
8
CABIN
CABIN
HOUSE
PUMP
1600 ft
2" PVC
LAKE
TAHOE

FIGURE 2-1 LAYOUT OF EXPERIMENTAL PONDS

the pond bottom near the south end of the structure. This standpipe could be removed for draining and cleaning of the pond between experiments, or assays.

Lake Tahoe Water (LTW) used in the pond assays was pumped directly from the lake by means of a centrifugal pump located near the shoreline. The pump intake was placed approximately 100 yd offshore in about 10 ft of water at 4 ft above lake bottom. The pump discharged through 2000 ft of 2-in. PVC pipe into a horizontal 6-in. PVC header supported on a superstructure of cabinets at an elevation of approximately 3 ft above the pond water surface and extending across the entire 8-pond installation. Flow into each pond was by gravity through a small plastic line originating in the common header and fitted with a valve, by which the rate was controlled to provide the desired detention period, or residence time. Excess water delivered to the header was discharged over the riser standpipe and returned to the lake via a natural drainage channel.

## Operation of Pond Experiments

The ponds were washed, rinsed, and filled with LTW before Assay 1 and before Assay 4. The residence time was adjusted before the assay began by regulating the quantity of LTW entering the ponds by way of the pond header pipe. The sample containing the enriching nutrient to be evaluated by assay was then pumped into the pond from a 5-gal plastic container by a Sigmamotor pump at a uniform rate appropriate to produce and maintain the desired concentration of sample in the LTW at the selected residence time, hence nutrient levels and growth of algae should increase to steady state simultaneously. Two reference ponds containing only LTW were maintained at the same residence time as the experimental ponds. Indigenous organisms contained in LTW were used for inoculation of the pond. Attempts to use stock cultures of S. gracile as a measure of growth rate during the previous year were unsuccessful.

The experimental design used in the pond assays is summarized in Table 2-1. The ponds were operated on an 8-, 5-, and 3-day detention time using both secondary and tertiary effluent from the South Tahoe Public Utilities District (STPUD) Water Reclamation Plant for the major nutrient source. Secondary effluent was obtained as grab samples from the clarifier effluent following activated sludge treatment. Tertiary effluent was obtained as grab samples from the effluent from the activated carbon filter units (before chlorination). Essentially, tertiary treatment consisted of precipitation with lime to remove phosphates, volatilization of ammonia gas in an ammonia stripping tower, pressure filtration, and activated carbon filtration. The effluent was collected and transported to the pond site as needed in approximately 100 to 200 gal lots, in 5-gal polyethylene bottles and generally used within one week after collection.

## TABLE 2-1

## EXPERIMENTAL DESIGN OF POND ASSAYS

| Assay No. | Residence Time ($\theta$) | Dates | Pond Number[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 8 days | 14 Jul-<br>8 Aug | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II |
| 2 | 5 days | 9 Aug-<br>22 Aug | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II |
| 3 | 3 days | 23 Aug-<br>3 Sep | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II | Lake Tahoe | 0.1% II | 1.0% II | 1.0% S-II |
| 4 | 8 days | 8 Sep<br>3 Oct | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE |
| 5 | 5 days | 4 Oct<br>17 Oct | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE |
| 6 | 3 days | 18 Oct<br>31 Oct | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE | Lake Tahoe | 2.0% III | 1.0% III | 1.0% III+TE |

[a] II is secondary effluent, S-II is simulated secondary effluent prepared by adding macronutrients, iron, and trace elements in excess plus $NH_3$-N and $PO_4$-P equivalent to the concentration measured in the secondary effluent (see Table A-1 in Appendix A), III is tertiary effluent, III + TE is tertiary effluent with quantities of iron and essential trace elements added (see Table A-1 in Appendix A).

### Physical and Chemical Analyses

Chemical and physical analyses of the pond water were made at regular intervals during each experiment. Grab samples were collected just below the water surface at the midpoint of the pond. Attached aquatic growths (primarily pennate diatoms) occurred on the pond surface below the water level. In order to obtain a representative sample the pond surfaces were thoroughly scraped with a rubber squeegee and the attached material was allowed completely to circulate for approximately one-half hour before the sample was withdrawn.

Routine chemical analysis was performed on both filtered and unfiltered pond samples. The analysis on the unfiltered samples were: SS, VSS, organic-N, $NH_3$-N, and total phosphorus. The filtered pond samples were analyzed for: organic-N, $NH_3$-N, $NO_2$-N, $NO_3$-N, total-N, $PO_4$-P, total-P, Fe, conductivity, and pH. Chemical analysis of the nutrient source to the pond included, in addition to the above, COD and BOD of the unfiltered samples; and calcium, chloride, and alkalinity in the filtered samples. Bioassays by means of flask cultures were also performed rountinely when the pond was considered to be operating under steady state.

### VSS as Estimator of Biomass

Contained in the 1969 progress report [3] is a list of several different exploratory techniques used for estimating biomass. Of the techniques examined VSS was chosen in the study because it had the highest consistent order of correlation with the other determined parameters, in addition to being easy to obtain by simple laboratory procedures without a detectable loss of precision.

## ENVIRONMENTAL DATA

A record of some of the environmental conditions prevailing during the period during which the outdoor ponds were operated is presented in Appendix B. Included are solar radiation, sky conditions, precipitation, daily temperature range, barometric pressure, and wind direction and velocity. Pond water temperature data are shown in Appendix B. Pond temperature measurements were made in one of the eight ponds by use of a temperature probe immersed in the water and connected to a continuous recorder located inside the adjacent laboratory building. Daily total solar spectrum values for the period of pond operation were obtained from a solar station located at the old Kaiser Estate fronting on Lake Tahoe, approximately five miles from the pond site. The remaining environmental data were obtained from the U. S. Coast Guard Station at Lake Forest, Lake Tahoe, located less than one-half mile from the laboratory and pond installation.

## ANALYSIS OF DATA

### Computer

The computer was utilized to analyze the data more efficiently, especially to obtain values of maximum growth rate, $\hat{\mu}$; log maximum growth rate, $\hat{\mu}_\ell$; mean maximum cell concentration at the end of the growth period, $\hat{X}$; nutrient concentration at one-half the maximum specific growth rate, $K_s$; yield coefficient, Y; and the decay rate, $K_d$.

### Statistical Comparisons

The computer was also utilized to determine the mean, coefficient of variation, range of 95 percent confidence levels, and correlation factors. These determinations and their significance are discussed in chapters which follow.

# CHAPTER III

# RESULTS OF POND ASSAYS

## ENVIRONMENTAL PARAMETERS

### INTRODUCTION

As noted in Chapter II, pond assays were made of the potential of secondary and tertiary waste water effluents to stimulate algal growth in Lake Tahoe water (LTW) by feeding small amounts of such effluents into experimental ponds through which lake water flowed at a controlled rate. However, in order to isolate and identify any effects of the waste water on algal growth, it was necessary to monitor changes in the lake water itself and, because one major objective of the project was concerned with the eutrophication of Lake Tahoe, to determine if possible the causes of any observed changes in its quality.

Although from the results of previous studies [1,3] there was no reason to expect that the water mass of the lake would change appreciably during the period of study herein reported, several sources of possible change in the quality of the pond waters are readily identifiable. First, the Lake Tahoe water was by design drawn from the near-shore shallow area (approximately 10-ft) in which algal response to added nutrients might be expected to be most pronounced. Next, sediments from shoreline and land development enter the lake periodically; and both sediments and attached diatoms in shallow water may be subject to pickup by wind induced wave action. In fact in the particular area of the pond installation sediment discharge to the lake occurred over an extended period in 1969, and although the lake water intake works of the project were moved from the previous (1968) location there could be no assurance that lake sediments in the vicinity of the intake were unaffected. Finally, the effect of wind and rain borne allochthonous (extraneous) material on the experimental ponds is vastly greater than on the lake itself.

To isolate the effect of nutrients on Lake Tahoe water, observations were made of climatological variations as well as of changes in chemical quality of the lake water at the experimental ponds.

### CLIMATOLOGICAL FACTORS

A graphical representation of solar radiation, mean pond water temperature, and mid-range air temperature (see Tables B-1 and B-2, Appendix B) pertaining during a sequence of six pond assays is presented in Figure 3-1. The mid-range air temperature is the calculated average of daily high and low values observed at the U. S. Coast Guard Station less than one-quarter mile from the pond installation. Thus it is not necessarily the same as the mean air temperature over 24-hr, but in the absence of a continuous temperature record, and for the purposes of the study it may be taken as a fair approximation of such a mean. Table 3-1, computed from Table B-1 and B-2, Appendix B show that the day-to-night air temperature range was appreciable throughout the period of study (Jul 10-Oct 31, 1969), and that the variation in pond water temperature was only about 20 percent of that of the air.

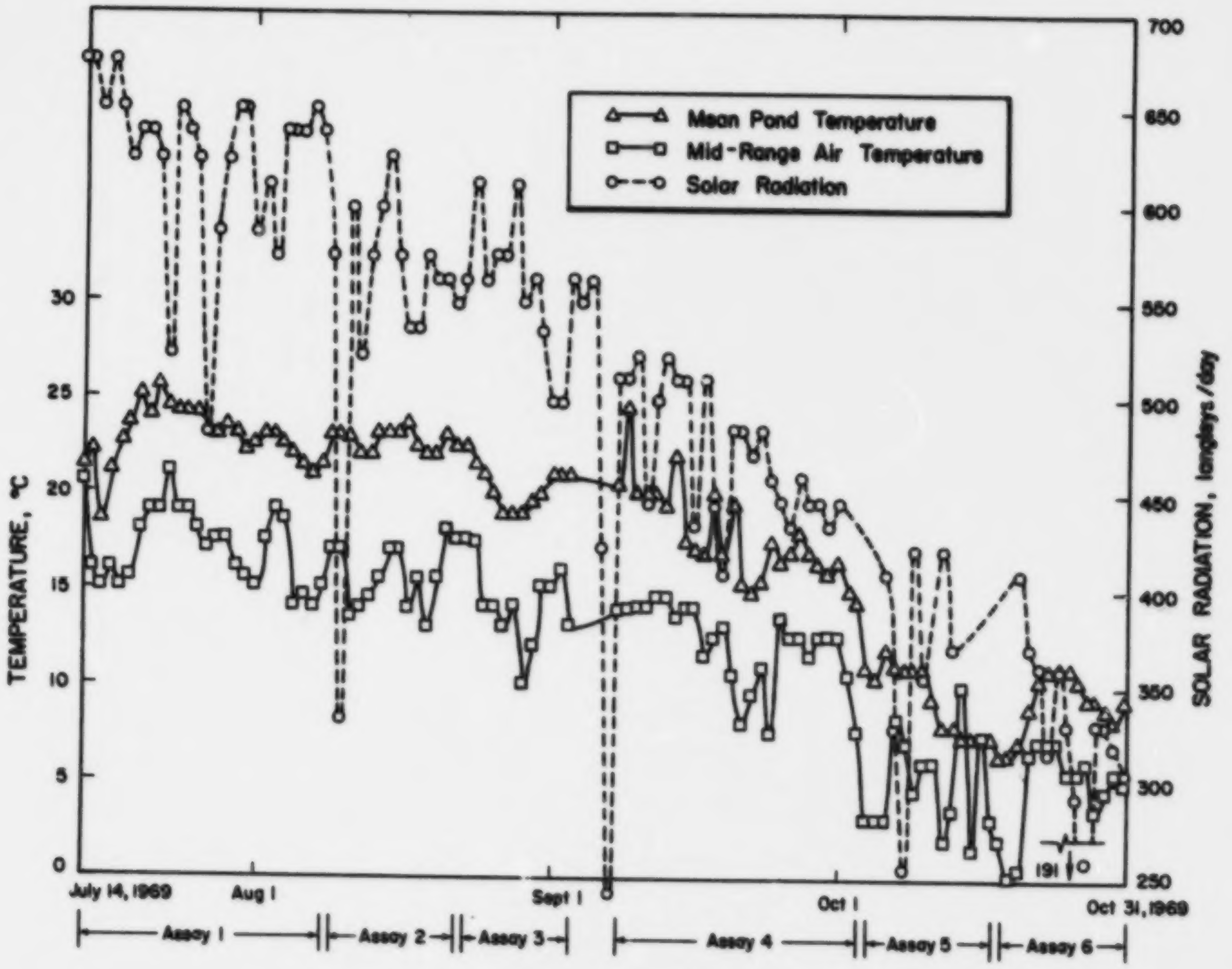

FIGURE 3-1. VARIATION IN ENVIRONMENTAL FACTORS DURING POND ASSAYS

## TABLE 3-1

## DAY-TO-NIGHT VARIATION IN AIR AND WATER TEMPERATURES

| Month (1969) | Air | | Pond Water | |
|---|---|---|---|---|
| | Range of Temperature Variation (°F) | Average Temperature Variation (°F) | Range of Temperature Variation (°F) | Average Temperature Variation (°F) |
| Jul | 19 - 42 | 35 | 6 - 9 | 7 |
| Aug | 34 - 47 | 41 | 5 - 9 | 7 |
| Sep | 18 - 46 | 35 | 3 - 8 | 6 (-) |
| Oct | 6 - 39 | 25 | 1 - 9 | 4.7 |
| Jul 10-Oct 31 | 6 - 47 | 34 (-) | 1 - 9 | 6.6 |

From Figure 3-1 it is evident that the mean water temperature tended to follow the mid-range air temperature. However, the changes were less abrupt. Two factors combine to bring about this slower response. The first is the limited thermal capacity of air as compared to water. The second is that the temperature of Lake Tahoe water at the pump intake depth (approximately 7 ft below the water surface) tends to be somewhat constant from day to night. Consequently, variation in pond water temperature is a function of air-water temperature relationships at the ponds only, and the effect is least evident as the hydraulic residence time is decreased.

From Figure 3-1 it may be seen that the mean daily pond water temperature was fairly uniform during the period when Assays 1 through 3 were in progress, whereas it steadily decreased during the fall season when Assays 4 through 6 were made. In contrast with the curves of air and water temperature, the curve of solar radiation shows essentially a constant downward trend from mid-July through October. During September and October the trends of air and pond water temperature curves generally parallel the trend of solar radiation, although during the warmer summer months when back-radiation from the earth at night is greatest, both air and water temperatures showed the expected lower rate of decrease with time than did solar radiation.

Decreasing pond water temperatures as well as reduced solar radiation input directly affects aquatic growth. For example, for bacterial systems a "rule of thumb" states that the "growth rate doubles for each 10°C increase in temperature." Presumably the reverse is also a valid assumption. It is noteworthy that during Assays 5 and 6 the pond water temperature was at or below the level (10°C) at which biological activity becomes seriously reduced. Therefore, although Figure 3-1 in itself shows nothing unusual from a climatological viewpoint, it does show changes during some assays which may be useful in interpreting the results of such assays in terms of growth stimulation in relation to added nutrients.

### VARIATION IN INFLUENT WATER QUALITY

Observations of the quality of water delivered to the pilot ponds were made approximately three times weekly on samples of Lake Tahoe water taken from the pond header. Results of the analyses of both filtered and unfiltered samples are summarized in Table C-1, Appendix C. Similar chemical analyses were made monthly on grab samples obtained directly from the lake near the intake works (see Figure 2-1), and at a point in the middle of Lake Tahoe. Results of these analyses appear herein as Table C-2, Appendix C.* Although the purpose of the monthly sampling was to identify seasonal and long-term changes in the quality of Lake Tahoe water, the near shore values are plotted on some of the header, or pond influent, graphs hereinafter presented, as a matter of interest and a possible check of data.

## Solids Concentration

The suspended solids (SS) and volatile suspended solids (VSS) observed during the July-October 1969 period of pond assays are presented in Figure 3-2. From the figure it is evident that the SS concentration fluctuated more than the corresponding VSS concentration, indicating that on occasion an excess of inorganic solids were entering the pond header water supply. Because Lake Tahoe is the only possible source of solids reaching the header, lake conditions must be responsible for the large increases in SS observed during October 1969. From Figure 3-2, however, it may be concluded that afternoon wind velocity, which might stir up lake sediments was not the sole cause. Nor could precipitation which occurred on October 15-17 (see Table B-1, Appendix B) have been responsible.

From Table B-1, Appendix B, it can be seen that on October 8, when the highest SS value was observed, the strongest wind reported for the July-October 1969 period blew constantly from the same direction (240°-250°) of azimuth. From Figure 3-3 it is evident that wind from the observed direction, although traversing only a short reach of lake before striking the LTW intake site, could be expected to generate wave and Seiche action at that site. This could not fail to stir up sediments brought into the lake prior to and during the 1969 study season as a result of shoreline development. Consequently, there is little doubt that wind velocity and sustained direction caused the observed rise in SS concentration on October 8. The situation was repeated on October 13, when less severe, but quite strong, winds prevailed all day from an azimuth direction of 230°. Strong winds from this same quadrant all day on October 16, gave rise to the highest VSS concentration observed. The final large increase in SS occurred on October 20. On this occasion a moderate wind blew from the third quadrant (Figure 3-3) during the morning and from the second quadrant during the afternoon. Winds in the 130°-150° azimuth direction traverse the lake from South Lake Tahoe to Tahoe City. Consequently they have a maximum reach and can be expected to affect the intake site by wave and Seiche action. A similar wind seems to have produced an SS peak in July. From available evidence there seems little doubt that the observed rise in SS concentration is a simple phenomenon of sediment disturbance due to wind.

In general the VSS curve shows peaks coincident with those for SS. No VSS data were recorded on October 8 at the time of the first major rise in suspended solids concentration. On October 13 and 20 the VSS concentration showed a moderate increase but not of the order observed for SS. However, on October 16, when the greatest VSS value observed during the study occurred, the suspended solids were essentially all volatile. The reason for this is not immediately evident. October 16 was preceded by a period of rapidly declining water temperature. Also it followed previous sediment disturbances. Table B-1 (Appendix B) shows that 0.90 in. of rain fell on the previous day, and 0.85 in. on the 16th. Considering that this was the

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*In interpreting the data in Tables C-1 and C-2 it is important to note that some values are reported in micrograms per liter (μg/ℓ) whereas others are reported in milligrams per liter (mg/ℓ)[i.e., (1000 x μg)/ℓ]. This generally leads to whole numbers in the table rather than small decimals. In the case of ammonia and phosphorus the values appear extremely large when expressed in μg/ℓ. For example, Table C-1 shows a value of 20,250 μg/ℓ $NH_3$-N in STPUD secondary effluent in July 1969 at a time when shore Lake Tahoe water (SLTW) had from 7 to 77 μg/ℓ. The advantage of using 20,250, 77 and 7 instead of 25.25, .077 and .007 is obvious. However, the reader should take care to observe the units in which various quality factors are herein expressed.

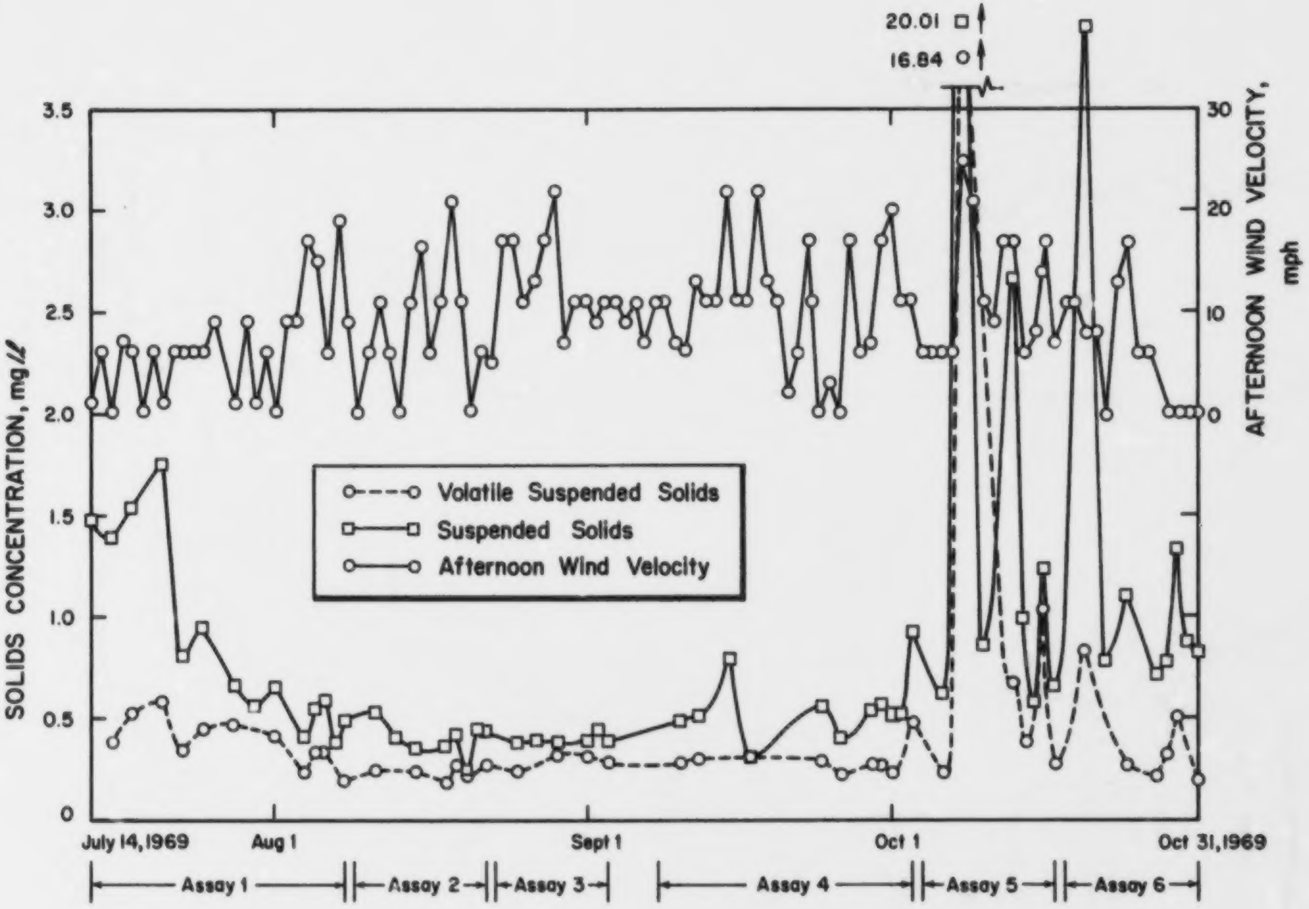

FIGURE 3-2. VARIATION IN SOLIDS CONCENTRATION IN NEAR-SHORE LAKE TAHOE WATER DURING POND ASSAYS (WIND VELOCITY ADDED)

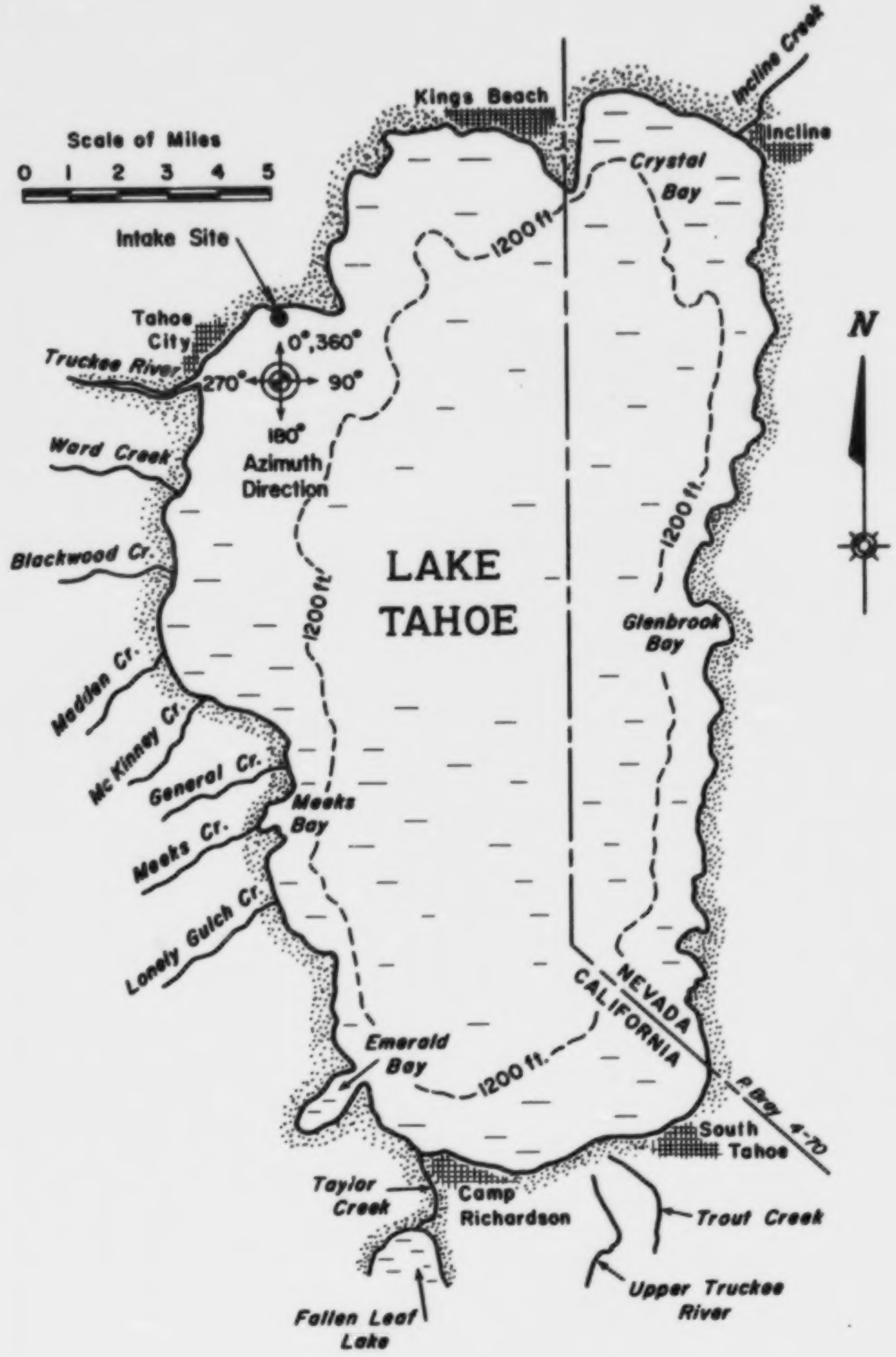
Scale of Miles
0 1 2 3 4 5
Intake Site
Tahoe City
Truckee River
0°,360°
270°
90°
180°
Azimuth Direction
Ward Creek
Blackwood Cr.
Madden Cr.
Mc Kinney Cr.
General Cr.
Meeks Cr.
Meeks Bay
Lonely Gulch Cr.
Emerald Bay
Taylor Creek
Camp Richardson
Fallen Leaf Lake
Kings Beach
Incline Creek
Incline
Crystal Bay
1200 ft.
LAKE TAHOE
Glenbrook Bay
NEVADA
CALIFORNIA
South Tahoe
Trout Creek
Upper Truckee River
N
P. Bray 4-70

FIGURE 3-3. AZIMUTH CHART FOR INTERPRETING WIND EFFECT ON NEAR-SHORE WATER QUALITY

first rainfall of any consequence for several months, shoreline development had been in progress during the summer, and the natural drainage of the area enters the lake near the intake site, it is concluded, though not clearly demonstrated, that wind mixing of organic-bearing surface runoff, was the most likely cause of the observed VSS rise.

## pH

Figure 3-4 shows that the hydrogen ion concentration of Lake Tahoe water at the pond header varied from 7.1 to 8.2 during the July to October period of study. In a general way the variation followed a seasonal trend observed from analysis of grab samples taken directly from the lake. The lowest value observed occurred just prior to the wind mixing of the shallows identified by changes in concentration of suspended solids (Figure 3-2). There is some indication that high values of pH follow similar high values of SS, but there is insufficient evidence to relate the two.

## Conductivity

Values in conductivity of pond header and grab samples reported in Tables C-1 and C-2, Appendix C, are plotted in Figure 3-5. In general the two show similar trends. The pond influent water, drawn from a depth of 7 ft below the surface, however, was consistently higher in conductivity than was surface water. In both August and September surface and header water samples were taken on the same date. On both occasions the deeper water was 8 to 10 micromhos greater in conductivity than surface water. There are several possibilities which might account for this observed difference but without confirming data there is little reason to speculate. The difference became minimal in October when events previously described resulted in vertical mixing in the shallows.

## Phosphorus

Variations in $PO_4$-P and total phosphorus observed in pond influent and near-shore Lake Tahoe surface water are summarized in Figures 3-6 and 3-7. In comparing the two curves it is important to note that values are in $\mu g/\ell$ and that the ordinates of the two figures are on different scales. Thus $PO_4$ varied from 1 to 11 $\mu g/\ell$ with most values falling in the 2 to 6 $\mu g/\ell$ range. Similarly the total phosphorus (Figure 3-7) varied from 2 to 60 $\mu g/\ell$, with only 7 of 43 observations outside a range of 4 to 25 $\mu g/\ell$. In both cases the monthly surface samples represent reasonably well the trend of phosphorus concentration at the 7-ft depth in shallow (approximately 10-ft) water. The principal major conclusion that can be drawn from Figures 3-6 and 3-7 is that the phosphorus concentration in Lake Tahoe water is small and in a range where the resolving power of the test procedures may be suspect; and that there was little identifiable change in the phosphate or total phosphorus concentration in the pond influent water over the period of the 6 pond assays (Figure 3-2).

## Ammonia and Nitrites Plus Nitrates

Figures 3-8 and 3-9 summarize data on $NH_3$-N and $(NO_2 + NO_3)$-N reported in Tables C-1 and C-2 (Appendix C). As in the case of phosphates, the values plotted are in $\mu g/\ell$ and the variation exaggerated by the scales used. As with other chemical constituents reported, the monthly grab sample of the near-shore lake surface water gives a fair representation of the water quality at a 7-ft depth in the same area. As might be expected when analyzing very low concentrations of nitrogen results of the more frequent samples show a considerable fluctuation. In comparing the two figures it is evident that nitrites and nitrates tended to increase as ammonia decreased, as might be expected; that the concentrations of the three forms of

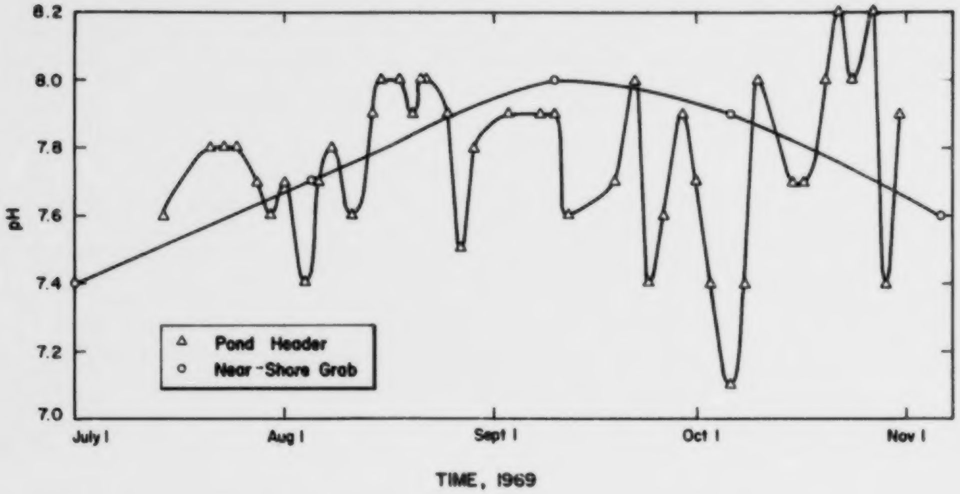

FIGURE 3-4. pH OF POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

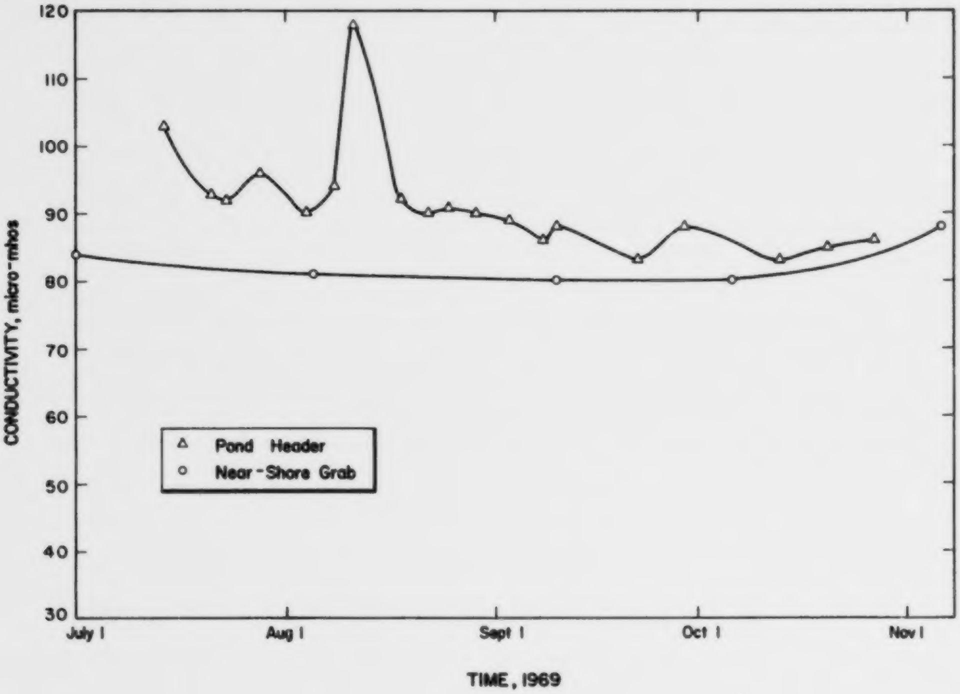

FIGURE 3-5. CONDUCTIVITY OF POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

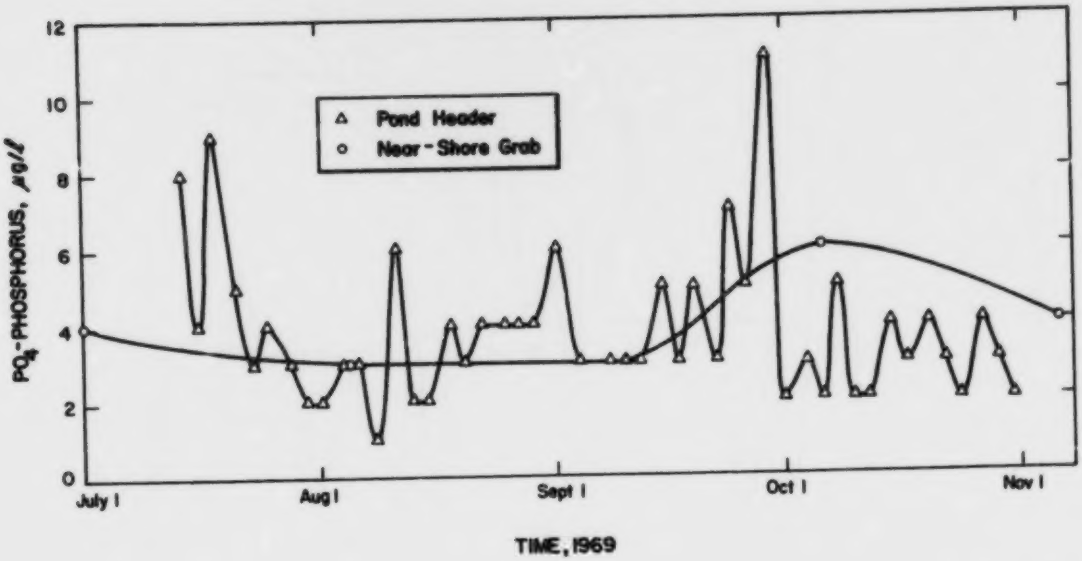

FIGURE 3-6. VARIATION IN $PO_4$-P; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

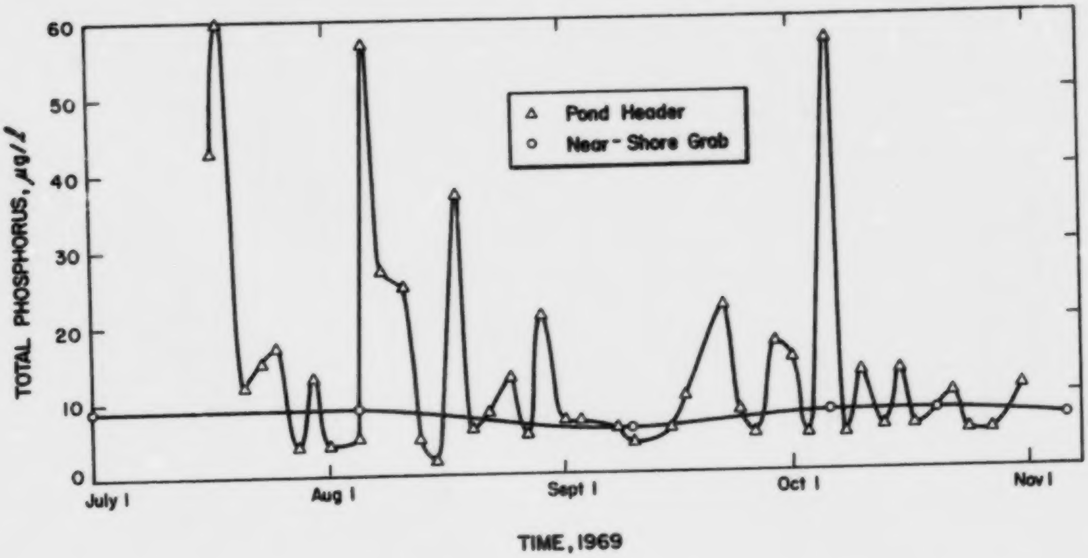

FIGURE 3-7. VARIATION IN TOTAL PHOSPHORUS; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

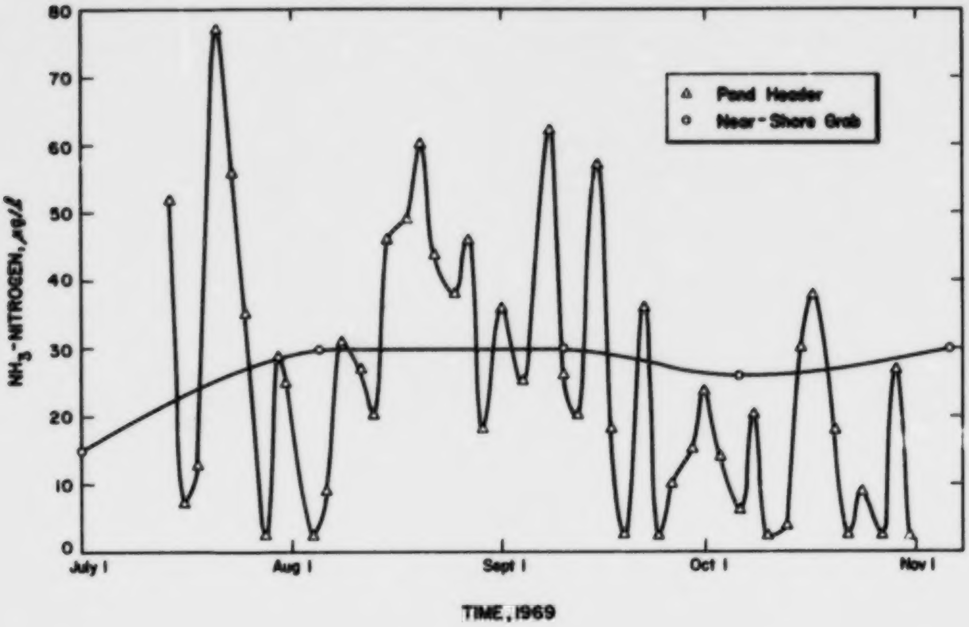

FIGURE 3-8. VARIATION IN CONCENTRATION OF AMMONIA; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

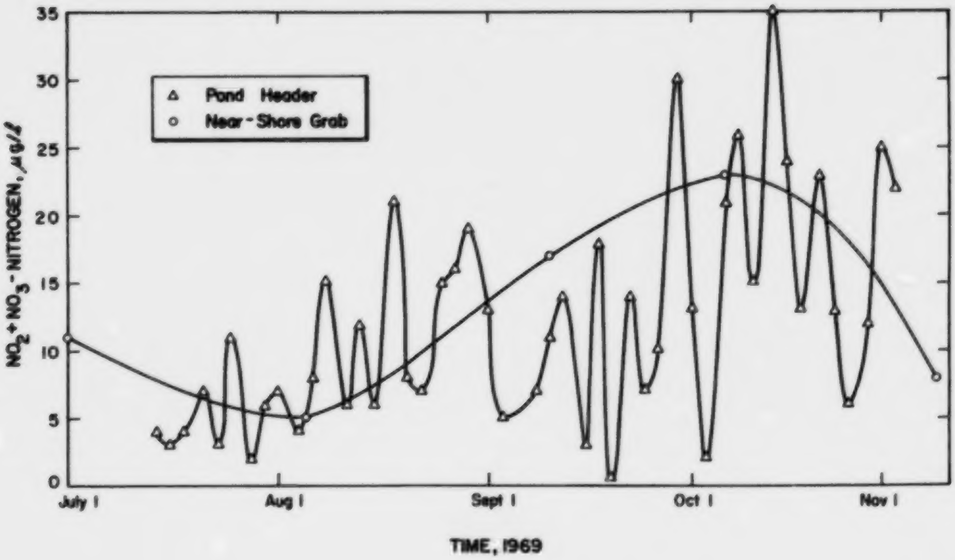

FIGURE 3-9. VARIATION IN CONCENTRATION OF $NO_2$+$NO_3$-NITROGEN; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

nitrogen in the shallow water of Lake Tahoe is quite small; and that a distinct seasonal change in $(NO_2 + NO_3)$-N occurred.

## Organic and Total Nitrogen

Figures 3-10 and 3-11 show the variation in concentration of organic and total nitrogen in pond influent and near-shore Lake Tahoe water during the July-October 1969 period of observation. Unlike the other forms of nitrogen, organic nitrogen appeared in greater concentration in the surface water than at lower depths. Thus the total nitrogen curves (Figure 3-11) reflect the same divergence. The data in all cases were obtained from filtered samples, hence the effects of organic material concentrated at or near the surface, rather than the material itself, must account for the higher organic nitrogen in surface samples. The precise causes of the observed phenomenon have not been established. During the summer months there was, as previously noted, development activity on the shore in an area of organic soil. Dust from this work was at times a local annoyance. Further from the shore, activity along Burton Creek which traverses other organic soils, may well have contributed small amounts of animal manures and other sources of nitrogen. The sampling point for near-shore water is near the mouth of Burton Creek, consequently it seems logical to assume that inputs from the creek had some influence. Aquatic life in the lake itself is principally attached forms, hence should exert its influence at lower depths, except as it may have originated elsewhere, surfaced and drifted into the sampled area. Windblown allochthonous material is also a probable source of surface organics. From Table B-1 (Appendix B) and Figure 3-3 it is clear that prevailing winds coming across forested land and along a populated waterfront could concentrate surface drift in the area from which the samples reported herein were collected.

## VARIATION IN WASTE WATER QUALITY

In addition to the analyses of pond influent water pumped from Lake Tahoe, Table C-1 (Appendix C) reports chemical analyses for secondary (STPUD II) and tertiary (STPUD III) effluents used as the source of added nutrients in the pond assays. From the table it may be noted that the influent Lake Tahoe water (SLTW) was analyzed more frequently than the effluent during any individual assay. For example, 15 analyses of influent water at the pond headers are reported during the course of Assay No. 1 (see Table C-1), whereas only 3 analyses of secondary effluent are reported during the same period. The table, however, does not strictly reflect the true situation. Additional analyses, not reported in Table C-1, were made of each batch of effluent during its time on the feed line in order to monitor any changes which might occur with time. The results showed that the composition of the feed effluent remained within the range of analytical variance satisfactorily during the period of use. However, the period of use could not be extended to cover the entire assay period. Consequently, it was necessary to bring in a new batch of effluent periodically. The effluent analyses reported in Table C-1 represent the composition of each of these new batches. The date reported in Column 1 of the table is the date of analysis rather than the date the effluent went on the assay feed line. However, the two dates were never far apart.

The principal source of variation in waste water quality during any given assay resulted from this need to change feed material. In some cases the change in effluent composition was negligible; in others there was appreciable variation in some constituents. However, the effect of changing feed material could not be overcome simply by adjusting the feed rate because not all constituents changed proportionally. Thus in the absence of any reliable knowledge of which constituent was controlling the growth rate, or of the combination of factors involved and the response of the pond organisms to them, there was no choice but to live with the changed composition of feed material reported in Table C-1 during individual assays.

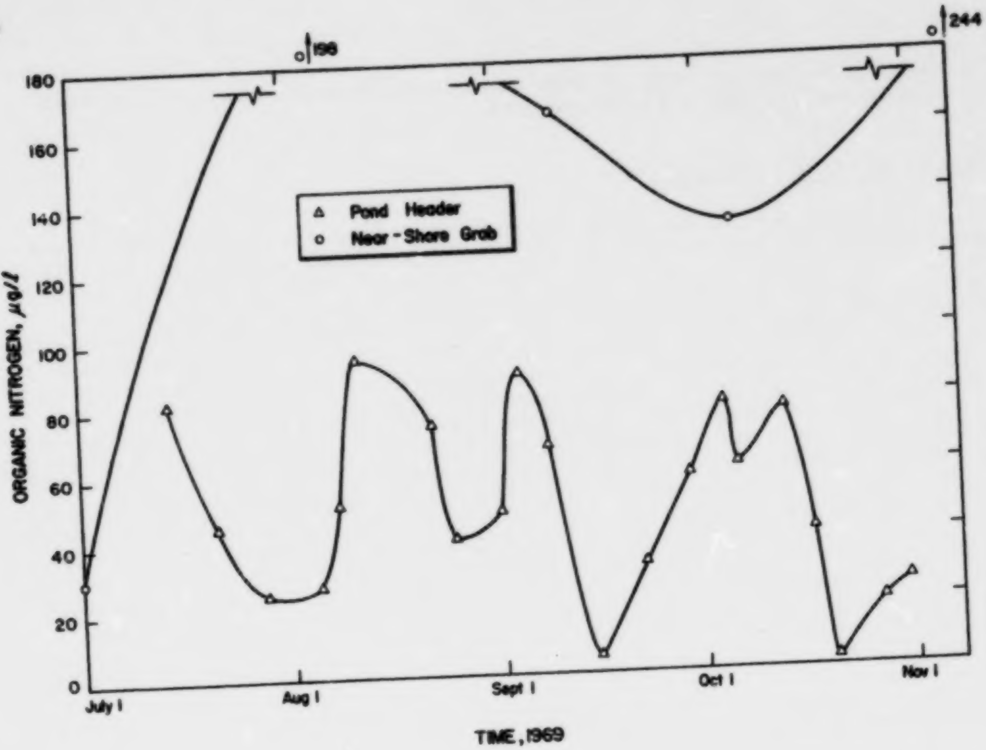

FIGURE 3-10. VARIATION IN CONCENTRATION OF ORGANIC NITROGEN; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

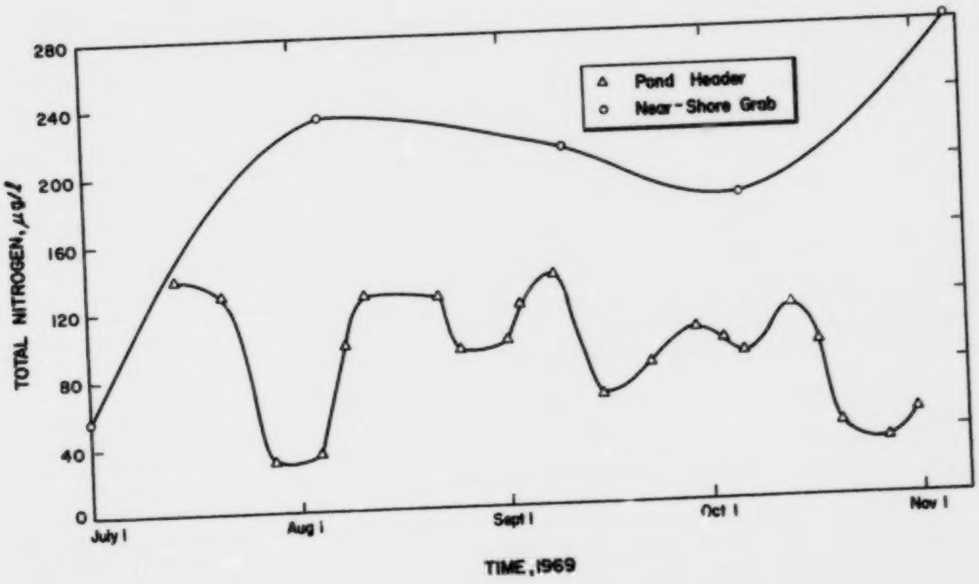

FIGURE 3-11. VARIATION IN CONCENTRATION OF TOTAL NITROGEN; POND INFLUENT AND NEAR-SHORE LAKE TAHOE WATER

## MID-LAKE VERSUS NEAR-SHORE WATER QUALITY

In a preceding section the variation in quality of Lake Tahoe water at a near-shore station was evaluated over the July-October 1969 period of pond assays, with particular emphasis on seasonal changes and on the similarity of surface and subsurface water. However, the true significance of the results of pond assays depends upon the similarity of the near-shore water used in the pond assays and the water mass of the lake itself. Moreover, an assay of the water mass is necessary before the influence of added nutrients on algal growth stimulation can be identified. Therefore, a lake water sampling program and a program of bioassay were early (1967-1968) incorporated into the program of study of the eutrophication of Lake Tahoe. In pond assays, Lake Tahoe water from the shallow inshore region was used as a control. To relate near-shore to mid-lake response, flask assays were made of grab samples from both the near-shore and mid-lake stations.

The results of chemical analyses of near-shore samples (SLT) and mid-lake samples (MLT) are summarized in Table C-2, Appendix C. Data in this table for the critical nutrient compounds of nitrogen and phosphorus show that:

1. Organic and total nitrogen samples taken at mid-lake and near-shore on the same day show a reasonably similar water quality at the two locations. There was a moderate increase in the concentration of both types during March; a decline which reached a low point at the end of June; and a large increase in July. Thereafter a slow decline set in at mid-lake which reached new lows in December. At the near-shore station the decline was along a path paralling that occurring at mid-lake. However, shore samples turned upward to a maximum for the year in early November; then declined as at mid-lake in December.

2. Ammonia and ($NO_2$ + $NO_3$) concentrations followed a less clear but generally same pattern as total and organic nitrogen. Concentrations were low and changes explosive, particularly in the case of $NH_3$.

3. Values of phosphate concentration were generally below 10 μg/ℓ and difficult to measure with accuracy. Nevertheless the $PO_4$ curves at shore and mid-lake stations were very close together except in December, when a wide divergence occurred.

4. Total phosphorus curves were roughly similar but much more variable at the near-shore station.

From a plotting of the data from Table C-2 (Appendix C), not herein reproduced, it is evident that the more conservative parameters, $PO_4$, total nitrogen, and ($NO_2$ + $NO_3$) show both a seasonal variation and a good agreement between near-shore and mid-lake concentrations. Considering the distance between sampling stations and the influences which might affect near-shore waters more than mid-lake water, it is concluded that the Lake Tahoe water pumped to the ponds was representative of the lake and hence, that the findings from the pond assays should be applicable to the lake in general.

### Flask Assays

Biomass measurements made by the flask assay method described in Chapter II are summarized in Table C-3, Appendix C, for both shore and mid-lake samples, as well as for surface runoff. Such flask assays serve a number of purposes of which the most immediate is to reveal any nutritional differences which may exist between the near-shore and deep portions of the lake, and so facilitate generalization from pond assays. Other purposes of flask assays of LTW important to the study herein reported include:

1. To determine the ability of the lake water to support algal growth.

2. To identify possible seasonal variations in the growth stimulating character of LTW.

3. To detect differences in Lake Tahoe and the creeks tributary to it.

Cell counts reported in Table C-3 represent the average of five replicate assays. From the raw data, growth rates, $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$, and the cell concentration, $\hat{X}_5$, were computed. To do this duplicate counts for each flask were averaged, and the resulting values were again averaged to obtain a mean count for the five replicates constituting the assay. By plotting these data against time, or by computer analysis, to obtain the maximum slope of the growth curve [1] the mean maximum growth rate $\hat{\mu}_b$ was obtained. $\hat{\mu}_{b\ell}$ was obtained by determining the log growth equation of best fit to the 1, 3, and 5 day cell count, utilizing the method of least squares programmed for computer analysis. $\hat{X}_5$ represents the maximum number of cells attained at the end of the 5-day growth period, evaluated as the average of replicate counts.

Values of growth rate and cell concentration observed in assays of mid-lake and near-shore waters are presented in Table 3-2. Included in the table are values previously reported [1] for 1968-1969. In terms of what the assay means relative to the eutrophication of Lake Tahoe it is, of course, subject to the limitation of the flask assay method - selected test alga, continuous lighting, time-depreciation of nutrient concentration, variable cell age, nutrient demand, etc. In this context the pond assays hereinafter discussed are more pertinent. However, the parameter does serve as a means for comparing the nature of near-shore and mid-lake waters, which was the objective of the assay. The same rationale applies to the growth rates $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$, which represent two different ways of evaluating the same phenomenon from one set of data. The object of computing both instead of but one was to explore the possibility that one might prove better than the other, as revealed by coefficients of variation and correlation coefficients.

During the July to December period of the study the test organism used was Selenastrum capricornutum instead of the S. gracile previously utilized. This change was desirable because, as noted in Chapter II, the former is more suitable for accurate cell counting by the Coulter Counter. Thus the numerical values reported prior to July 1970 do not necessarily correspond to those reported thereafter, as two different species of the same genus may not show identical responses.

In interpreting the growth rate data in Table 3-2 the apparent time for biomass to double itself may be obtained by dividing the $\hat{\mu}_b$ values into the natural logarithm of 2 (i.e., 0.693). From such a calculation a range of from 1.0 to 4.0 days results for the shore samples during the July-December 1969 period, and from 0.4 to 4.0 days at mid-lake. Average values for the two stations were 2 (+) and 2.2 days, respectively. Table 3-2 shows that the cell count, $\hat{X}_5$ for the July-December 1969 period was somewhat more consistent than growth rates in relating shore and mid-lake waters. In any case the data support, as did chemical analyses, the conclusion that near-shore waters are generally representative of the lake, and hence that the results of pond assays can be interpreted in terms of other sectors of the lake water under similar conditions of temperature, depth, and added nutrients.

The relationship between various parameters and between algal growth response and various nutrients are shown for mid-lake samples in Figure 3-12; and for near-shore samples in Figure 3-13. From these figures it is apparent that although there was some minor differences between parameters, all measures of biomass production relate to the concentration of organic nitrogen and total nitrogen in a similar fashion. Curves for ammonia and phosphorus likewise tend to parallel growth curves but the concentrations are small and the relationship less pronounced. $(NO_2 + NO_3)$-N occurs in such small concentrations that at neither mid-lake or shore is their effect evident in Figures 3-12 and 3-13.

## TABLE 3-2

### MAXIMUM GROWTH RATES AND MAXIMUM CELL CONCENTRATIONS ATTAINED AT THE END OF FIVE DAYS IN FLASK CULTURE OF LTW

| Sampling Date | Maximum Growth Rate ($\hat{\mu}_b$, day$^{-1}$) | | | | Maximum Growth Rate ($\hat{\mu}_{bf}$, day$^{-1}$) | | | | Maximum Cell Concentration ($\hat{X}_s$, cells/mm$^3$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mid-Lake Sample | Coef. Var. (%) | Shore Sample | Coef. Var. (%) | Mid-Lake Sample | Corr. Coef. | Shore Sample | Corr. Coef. | Mid-Lake Sample | Coef. Var. (%) | Shore Sample | Coef. Var. (%) |
| 6/15/68[a] | 0.428 | 36.7 | 0.454 | 21.0 | 0.278 | 0.920 | 0.255 | 0.881 | 274.8 | 12.6 | 255.4 | 19.8 |
| 7/15/68[a] | 0.510 | 49.0 | 0.302 | 15.6 | 0.293 | 0.896 | 0.223 | 0.955 | 194.2 | 42.6 | 151.6 | 8.4 |
| 8/ 9/68[a] | 0.550 | 16.0 | - | - | 0.293 | 0.923 | - | - | 168.2 | 19.7 | - | - |
| 9/13/68[a] | 0.512 | 17.6 | 0.324 | 35.5 | 0.378 | 0.955 | 0.336 | 0.929 | 230.4 | 47.7 | 195.6 | 29.5 |
| 10/ 4/68[a] | 0.330 | 41.2 | 0.634 | 37.3 | 0.049 | 0.282 | 0.247 | 0.752 | 62.4 | 25.8 | 126.0 | 14.4 |
| 11/ 8/68[a] | 0.350 | 30.6 | 0.562 | 8.6 | 0.199 | 0.881 | - | - | 119.8 | 30.2 | 144.2 | 22.5 |
| 12/ 3/68[a] | 0.796 | 14.8 | 0.368 | 49.5 | 0.548 | 0.947 | 0.207 | 0.811 | 168.6 | 31.7 | 37.8 | 22.5 |
| 1/ 3/69[a] | 0.270 | 37.8 | 0.372 | 40.7 | 0.140 | 0.811 | 0.231 | 0.875 | 69.0 | 10.0 | 104.0 | 25.0 |
| 2/ 4/69[a] | 0.203 | 34.2 | 0.633 | 18.6 | 0.149 | 0.867 | 0.360 | 0.872 | 54.4 | 14.7 | 147.6 | 20.5 |
| 3/ 6/69[a] | - | - | 0.379 | 18.3 | - | - | 0.318 | 0.935 | - | - | 162.6 | 29.1 |
| 3/15/69[a] | 0.470 | 25.6 | - | - | 0.361 | 0.914 | - | - | 185.2 | 28.0 | - | - |
| 4/ 1/69[a] | - | - | 0.517 | 13.7 | - | - | 0.349 | 0.956 | - | - | 181.8 | 7.0 |
| 5/ 6/69[a] | 0.227 | 29.1 | 0.640 | 22.1 | 0.119 | 0.832 | 0.350 | 0.885 | 96.4 | 7.7 | 223.0 | 4.5 |
| 6/ 4/69[a] | - | - | 0.444 | 50.9 | - | - | 0.220 | 0.710 | - | - | 102.6 | 14.1 |
| 6/ 9/69[a] | 0.205 | 91.1 | - | - | 0.070 | 0.435 | - | - | 69.2 | 17.4 | - | - |
| 7/ 1/69[a] | 0.406 | 8.8 | 0.446 | 3.6 | 0.279 | 0.954 | 0.290 | 0.951 | 129.4 | 11.4 | 133.7 | 8.5 |
| 7/ 1/69[b] | 0.069 | 23.6 | 0.135 | 11.1 | 0.046 | 0.915 | 0.116 | 0.990 | 65.8 | 2.6 | 90.0 | 2.4 |
| 8/ 5/69[b] | 0.055 | 39.1 | 0.209 | 12.4 | 0.043 | 0.079 | 0.110 | 0.865 | 61.5 | 7.4 | 97.5 | 5.8 |
| 9/10/69[b] | 0.386 | 39.2 | 0.363 | 36.4 | 0.262 | 0.877 | 0.153 | 0.690 | 219.3 | 41.5 | 136.1 | 21.6 |
| 10/ 6/69[b,c] | 0.348 | 9.5 | 0.249 | 15.3 | 0.192 | 0.886 | 0.175 | 0.922 | 99.5 | 12.1 | 102.3 | 10.7 |
| 11/ 6/69[b] | 0.579 | 24.0 | 0.571 | 10.6 | 0.310 | 0.871 | 0.349 | 0.933 | 203.4 | 5.1 | 263.9 | 6.0 |
| 12/12/69[b] | - | - | 0.236 | 32.4 | - | - | 0.160 | 0.878 | - | - | 201.1 | 10.8 |
| 12/14/69[b] | 0.217 | 19.7 | 0.242 | 22.6 | 0.168 | 0.933 | 0.168 | 0.941 | 133.4 | 15.7 | 139.7 | 6.9 |

[a] Selenastrum gracile used as test organism.

[b] Selenastrum capricornutum substituted for S. gracile at this sampling date.

[c] Sample date 10/6/69 cultures were seeded with Chlorella contaminated S. capricornutum.

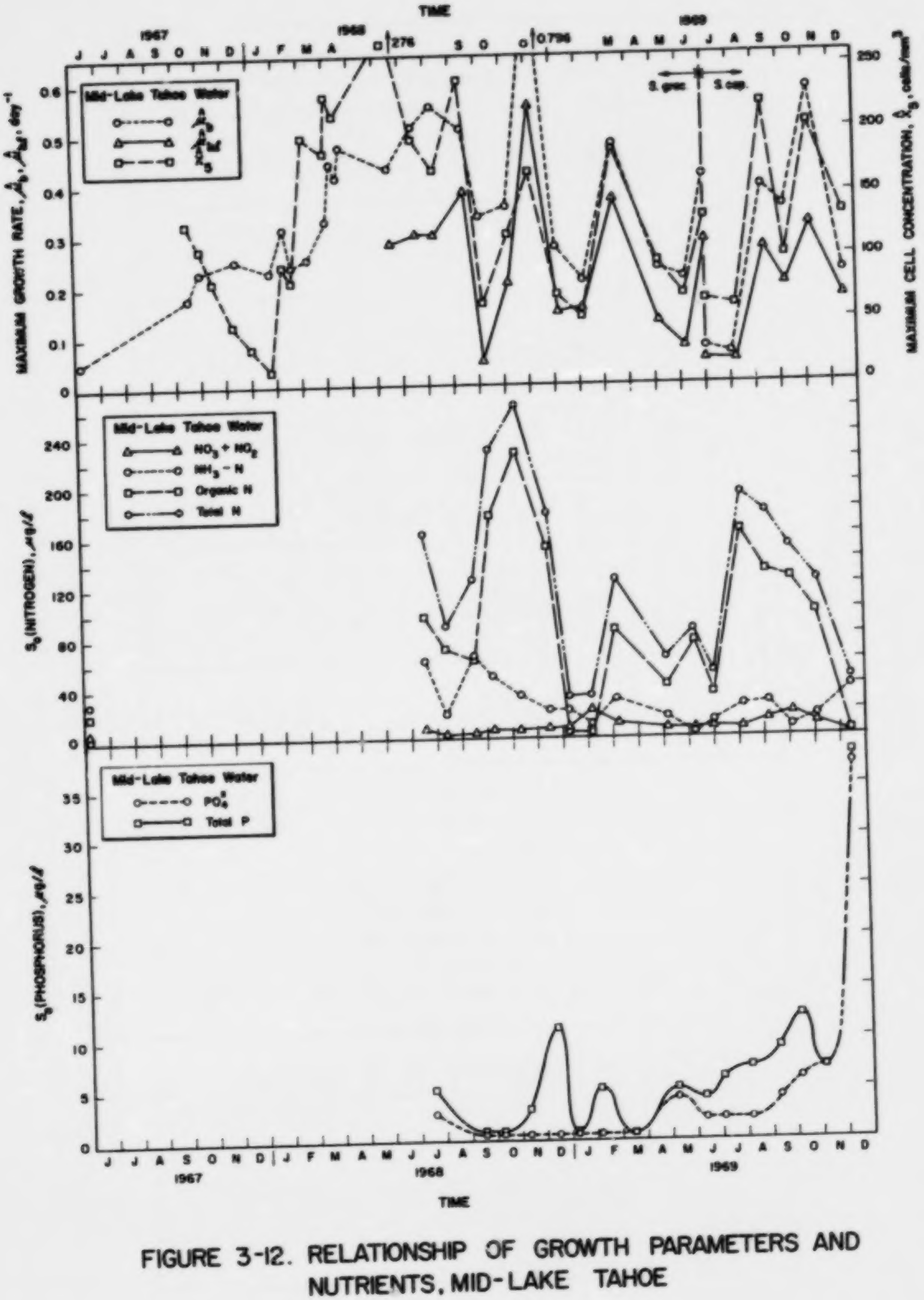

FIGURE 3-12. RELATIONSHIP OF GROWTH PARAMETERS AND NUTRIENTS, MID-LAKE TAHOE

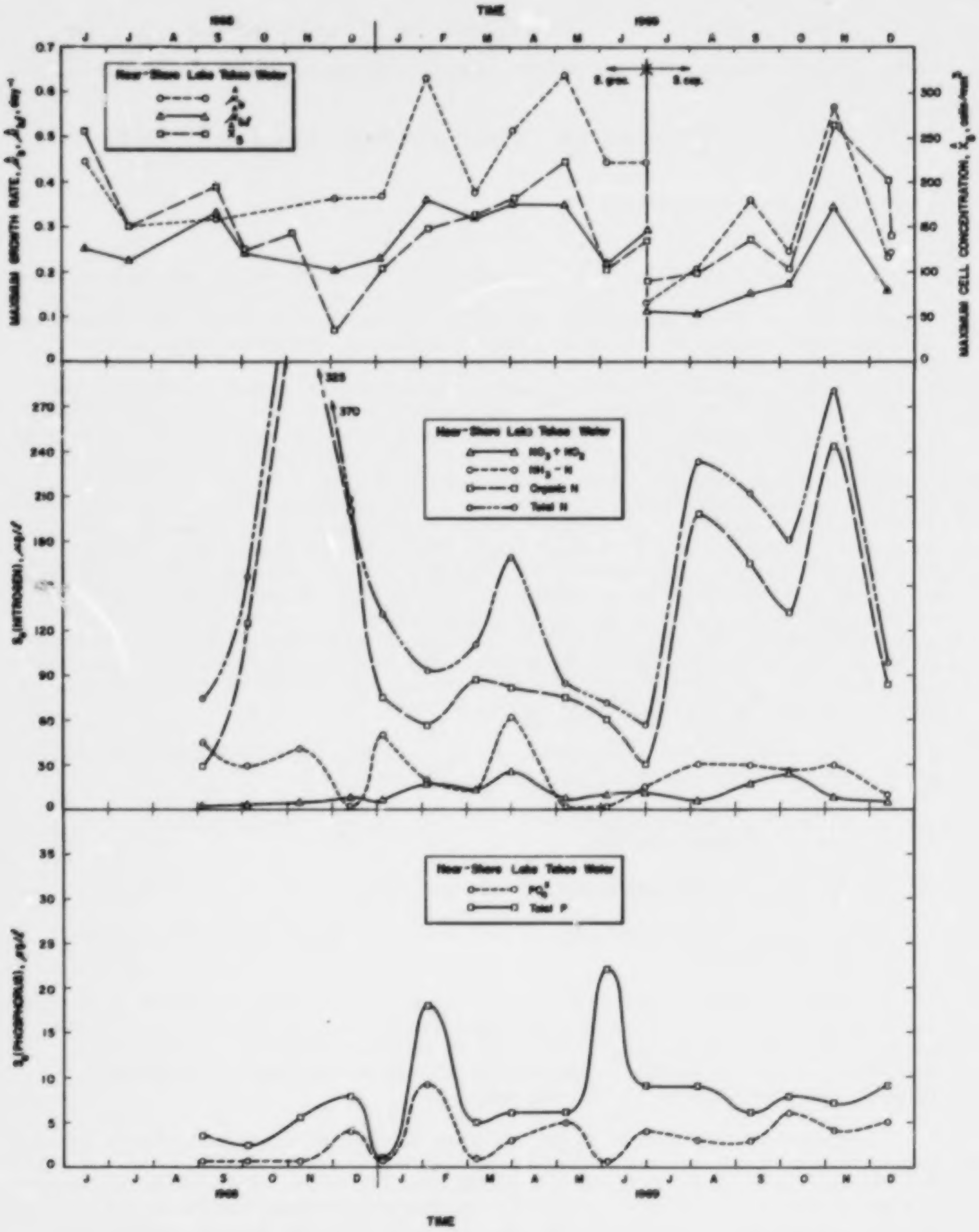

FIGURE 3-13. RELATIONSHIP OF GROWTH PARAMETERS AND NUTRIENTS, NEAR-SHORE LAKE TAHOE

From Figures 3-12 and 3-13 and Table 3-2 it may be concluded that the variation in algal growth reported in Table 3-2 was a response to nutrient concentration, particularly nitrogen, rather than to any random errors in technique.

## EFFECTS OF SECONDARY AND TERTIARY EFFLUENTS ON LAKE TAHOE WATER

### INVENTORY OF QUALITY PARAMETERS IN POND ASSAYS

As summarized in Table 2-1 (Chapter II), six pond assays were made during the period July 14 to October 31, 1969. In each of these, replicate ponds were assigned to Lake Tahoe water (LTW) without added nutrient sources. The remaining six ponds were similarly paired to permit simultaneous assay of three different types of added nutrients. Random pairing to minimize any effect of position in the series was adopted. Ponds hereinafter referenced by number were positioned as shown in Figure 2-1 (Chapter II). As a supplement to measures of growth rate and cell mass production, an inventory and rough materials balance, was undertaken to account for the major constituents of the pond water involved in changes in biomass. For this purpose, calculations were made from the initial (Table C-1, Appendix C) and final (Table D-1, Appendix D) concentrations of several individual water quality parameters, or constituents. Suspended (SS) and volatile (VSS) suspended solids; organic-N, $NH_3$-N, $(NO_2 + NO_3)$-N, total inorganic-N, and total N; $PO_4$-P and total-P; and conductivity were the parameters inventoried. The results of the most pertinent of these inventories are presented hereinafter in a series of tables which summarize only the final relationship of input to output of a particular quality factor. A positive (+) sign is used in the table to indicate an input in excess of output of material in its original (input) form. Conversely, a negative (-) sign indicates that more material appeared in the effluent than entered the system as a given compound or factor.

The tables do not represent a strict mass balance of material because of several generally unavoidable assumptions, including:

1. No material entered the ponds except by way of Lake Tahoe water and the added nutrient feed.

2. Evaporation and precipitation were negligible.

3. Constituent concentrations in the ponds were equal to concentrations in the outflow.

Such assumptions are of varying degrees of validity. The first is perhaps the most visionary. Allochthonous material transported by the wind did indeed get into the ponds in varying amounts and at no predictable or constant rate. Moreover, some of it settled, some stayed in suspension, some was presumably soluble, and some floated on the surface.

Except for one period in October near the end of Assay No. 5 there was no precipitation of consequence. However on that one occasion about 1.7 in. of rain fell in two days. What it brought into the ponds in terms of particulate matter and nutrients is not readily estimated. As for evaporation, values of 0.1 to 0.2 in. per day are possible in the area but vary with the season. Measurement was beyond the scope of the study, hence no evaporation data were available.

Assumption number 3 is reasonably valid in the case of dissolved material, because of constant mixing of the tank contents by whirlpool pumps. It is of less validity in the case of attached solids or settleable solids too large to be significantly disturbed at the mixing rate which prevailed because the indigenous lake algae responsible for biomass increase and utilization of nutrients are mostly attached forms of diatoms. As noted in Chapter II, the sides and bottom of the tank were squeeged and the tank contents thoroughly mixed before each sampling for biomass

(VSS, mg/ℓ) determination. This minimized the error in growth rate calculations; and maximized it for solids inventory because it led to the assumption that the observed solids concentration pertained throughout the period between samplings. In reality, the solids thus obtained represented those constantly present in the pond effluent, plus those that had accumulated since the last squeegeeing and mixing routine. The imprecision inherent in assumption 3 is not a result of faulty experimental design. Rather it is the penalty which must be paid when outdoor pilot experiments simulate natural conditions, with all the uncontrollable variables associated with such conditions.

## SS and VSS

Tables 3-3 and 3-4 summarize the results of inventories of suspended and volatile solids for all ponds and all pond assays. Subject to the limitations discussed in the preceding paragraph, they account for algal growth which took place in the ponds during the six assay experiments. An inspection of these tables shows that most values are negative. This is consistent with the concept, and the observed fact, that algal cells increased during the assay at the expense of dissolved nutrients.

TABLE 3-3

INVENTORY OF SUSPENDED SOLIDS IN POND ASSAYS
(all values in grams)

| Pond No. | | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | LTW | - 19 | - 26 | - 32 | - 14 | + 19 | - 47 |
| 5 | | - 17 | - 27 | - 40 | - 5 | + 9 | - 28 |
| 2 | Sewage Effluents | - 53 | - 55 | - 47 | - 17 | + 9 | - 265 |
| 6 | | - 26 | - 41 | - 54 | + 17 | - 3 | - 270 |
| 3 | Sewage Effluents | - 113 | - 211 | - 186 | - 19 | - 4 | - 137 |
| 7 | | - 119 | - 235 | - 228 | - 3 | + 20 | - 78 |
| 4 | Chemical Nutrients[a] | - 90 | - 263 | - 168 | - 18 | - 5 | - 111 |
| 8 | | - 123 | - 269 | - 286 | - 3 | - 13 | - 93 |

[a] Assay 1 to 3 was simulated secondary effluent; Assay 4 to 6 was tertiary effluent plus trace elements.

## TABLE 3-4

## INVENTORY OF VOLATILE SUSPENDED SOLIDS IN POND ASSAYS
(all values in grams)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | - 9 | - 8 | - 9 | - 1 | - 1 | - 11 |
| 5 | - 10 | - 7 | - 9 | - 1 | - 1 | - 11 |
| 2 | - 18 | - 18 | - 13 | - 6 | - 13 | - 82 |
| 6 | - 14 | - 13 | - 30 | + 14 | - 18 | - 105 |
| 3 | - 65 | - 95 | - 109 | - 8 | - 18 | - 42 |
| 7 | - 67 | - 107 | - 151 | - 2 | - 3 | - 25 |
| 4 | - 52 | - 109 | - 79 | - 13 | - 13 | - 34 |
| 8 | - 63 | - 113 | - 111 | - 5 | - 20 | - 34 |

An evaluation of Table 3-3 and 3-4 in the light of Table 2-1 (Chapter II) reveals that the negative values, indicative of cell growth, tend to increase as the added nutrient concentration increases. For example, Pond No. 1 and 5, containing unfortified LTW show the lowest increase; and Ponds No. 3 and 7, containing 1% secondary effluent show the greatest. The tables also show in most instances a reasonable degree of compatability between the two ponds constituting an assay of any particular material. The widest deviations from this general case appears in Table 3-3, Assay No. 5, when input exceeded output. As discussed in relation to Figure 3-2, Assay No. 5 was in progress in October when wind and weather conditions brought in a very large amount of suspended solids which were not volatile. It is notable that volatile solids in Assay No. 5 (Table 3-4) failed to show the positive values or wild fluctuation evident in suspended solids.

### Nitrogen Compounds

Tables 3-5, 3-6, 3-7, and 3-8 summarize the change in various nitrogen compounds during each of the several pond assays. In each case where nutrients were added (i.e., Ponds 2,6; 3,7; and 4,8) essentially all of the values are positive, indicating by the convention adopted (see page 30) that more nitrogen went into the assay in the forms indicated in the table headings than came out of the ponds in that same form. In the case of the Lake Tahoe water (LTW) control ponds (i.e., Pond 1,5, all assays) the consistency between duplicate ponds was not as great for nitrogen as for volatile solids or suspended solids. The greatest disagreement between Ponds 1 and 5 seems to have occurred with ammonia. Only Assay No. 5 showed a consistent loss of ammonia. In other assays gains and losses appear quite random. This inconsistency is a result of both the small amount of ammonia present, the limitations of assumption, the precision of measurement possible at low concentrations, and unobserved biochemical changes which probably occurred in the pond biomass. The more conservative forms of nitrogen, ($NO_2$ + $NO_3$), although in low concentration, showed a somewhat more consistent check in LTW ponds. Inorganic and total nitrogen showed more gains than losses in Assays 4, 5, and 6. A number of reasons for such an occurrence in the fall of the year in contrast with earlier seasons may be identified, but because they do not document a materials balance they are not listed herein.

Relative to assays of LTW with added nutrients, the most consistent pattern is evident in Ponds 4 and 8 to which chemicals in the form of $K_2HPO_4$, $NH_4Cl$, iron,

## TABLE 3-5

## INVENTORY OF SOLUBLE AMMONIA-N IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | - 44 | 65 | - 87 | - 277 | 296 | - 354 |
| 5 | 623 | - 43 | 6 | - 687 | 262 | - 521 |
| 2 | 600 | 609 | 872 | 1238 | 1858 | 5180 |
| 6 | 874 | 214 | 184 | 225 | 734 | 4015 |
| 3 | 3903 | 4945 | 5376 | 427 | 806 | 1949 |
| 7 | 4585 | 4549 | 5662 | 1044 | 630 | 1501 |
| 4 | 2072 | 3814 | 4865 | 827 | 1400 | 1800 |
| 8 | 2143 | 3735 | 4886 | 461 | 945 | 1914 |

## TABLE 3-6

## INVENTORY OF SOLUBLE ($NO_2$ + $NO_3$)-N IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 87 | 46 | - 21 | 3 | 187 | 127 |
| 5 | 88 | 63 | 24 | - 0 | 121 | 153 |
| 2 | 220 | 76 | 80 | - 381 | - 14 | 118 |
| 6 | 209 | 68 | 172 | - 80 | 97 | 52 |
| 3 | 834 | 356 | 832 | 50 | 20 | 80 |
| 7 | 880 | 334 | 838 | 53 | 18 | 73 |
| 4 | 123 | 52 | 127 | - 55 | - 96 | - 239 |
| 8 | 138 | 51 | 153 | - 24 | - 132 | - 151 |

## TABLE 3-7

## INVENTORY OF SOLUBLE TOTAL INORGANIC-N IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 44 | 111 | - 108 | - 273 | 483 | - 227 |
| 5 | 712 | 21 | 29 | - 693 | 383 | - 367 |
| 2 | 820 | 684 | 952 | 858 | 1844 | 5298 |
| 6 | 1083 | 282 | 356 | 145 | 831 | 4066 |
| 3 | 4737 | 5300 | 6209 | 478 | 826 | 1868 |
| 7 | 5465 | 4883 | 6499 | 1097 | 648 | 1575 |
| 4 | 2195 | 3866 | 4992 | 772 | 1304 | 1562 |
| 8 | 2281 | 3785 | 5037 | 436 | 812 | 1762 |

## TABLE 3-8

## INVENTORY OF SOLUBLE TOTAL-N IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 451 | 179 | 66 | - 795 | - 2898 | - 135 |
| 5 | 633 | 230 | 1184 | - 687 | - 39 | - 2397 |
| 2 | 499 | 106 | - 2480 | 703 | 2044 | 2344 |
| 6 | 1202 | 604 | - 1479 | 1011 | 1448 | 3702 |
| 3 | 4875 | 5228 | 2390 | 574 | 404 | 801 |
| 7 | 4696 | 4584 | 3676 | 1250 | 381 | 325 |
| 4 | 1609 | 2994 | 1398 | 798 | 595 | 1982 |
| 8 | 604 | 2295 | 2983 | 27 | 1161 | 2270 |

and trace elements were added to LTW in Assays 1, 2, and 3 to provide P and N at approximately the same levels observed in the effluent fed to Ponds 3 and 7.

From the inventory of nitrogen compounds it may be concluded that with limited exceptions a decrease in all forms of nitrogen occurred, indicating that biomass was increasing, as previously shown by an increase in volatile solids (Table 3-4).

## Phosphorus

Changes in the amount of phosphorus entering and leaving the ponds, as measured by analyses for $PO_4$-P and total P, are summarized in Tables 3-9 and 3-10. Phosphorus concentration being extremely low in Lake Tahoe water, the inconsistant inventory data shown in the tables for Ponds 1, 5 are not surprising. $PO_4$-P values are consistent between replicate ponds in essentially all cases during Assays 1, 2, and 3, in which secondary effluent was the added source of nutrients (except Ponds 4 and 8; chemically fortified LTW). Assays 4, 5, and 6, involving various dilutions of tertiary effluent show a much smaller loss of phosphorus than Assays 1, 2, and 3; and (Table 3-4) a correspondingly low increase in volatile solids. Because phosphorus removal was a major aspect of tertiary treatment the results may mean that this element (P) was the growth limiting factor in Assays 4, 5, and 6.

TABLE 3-9

INVENTORY OF SOLUBLE $PO_4$-P IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 10 | 21 | 3 | - 9 | - 10 | 24 |
| 5 | - 4 | - 3 | 3 | 18 | - 17 | 3 |
| 2 | 157 | 113 | 167 | 55 | 68 | 128 |
| 6 | 122 | 143 | 188 | 44 | 60 | 105 |
| 3 | 1974 | 1416 | 1854 | 50 | 8 | 43 |
| 7 | 1898 | 1474 | 2057 | 37 | 41 | 62 |
| 4 | 2209 | 1738 | 1955 | 64 | 32 | 32 |
| 8 | 2304 | 1801 | 2103 | 52 | 41 | 14 |

## TABLE 3-10

## INVENTORY OF SOLUBLE TOTAL P IN POND ASSAYS
(values in mg)

| Pond No. | Assay Number (See Table 2-1, Chapter II) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | - 30 | - 672 | 98 | 33 | 97 | 74 |
| 5 | 26 | - 236 | - 56 | 34 | 119 | 26 |
| 2 | - 93 | - 80 | 77 | 11 | 172 | 163 |
| 6 | 90 | - 265 | - 264 | 82 | 221 | 187 |
| 3 | 1656 | 981 | 1865 | 74 | 247 | 138 |
| 7 | 1527 | 1142 | - 2121 | - 48 | 217 | 107 |
| 4 | 1909 | 1410 | 1970 | 130 | 272 | 85 |
| 8 | 1889 | 1536 | 2108 | 73 | 101 | 46 |

### Growth Limiting Nutrient

To evaluate the presumptive evidence that phosphorus was growth limiting in Assays 4, 5, and 6 the nitrogen/phosphorus ratio was computed for two cases – $NH_3$-N vs $PO_4$-P; and total inorganic N vs $PO_4$-P. The results are presented in Table 3-11. Because the purpose of the computation was to identify the growth limiting factor rather than to separate the stimulatory effect of LTW and added nutrients the data in the table reflect the actual situation in the pond within the limits of error and assumption. LTW (Ponds 1 and 5) is omitted from the table because at the low concentration of nutrients in LTW negative values are experimentally unavoidable (see Tables 3-4 – 3-10).

In interpreting the data in Table 3-11 use may be made of the general rule that an N/P ratio less than 10 identifies a nitrogen limiting situation, whereas a N/P ratio of 15 or more indicates that phosphorus was the limiting factor. From such criteria it may be concluded that all of the secondary effluent, and simulated secondary effluent assays (Assays 1, 2, and 3) were definitely nitrogen limited; and that with but few exceptions the tertiary effluents were phosphorus limited.

Variations in data from pond to pond in Assays 4, 5, and 6 are considerable. However, it is important to remember that phosphate concentrations were low, and that the assays covered a period of time when temperatures were dropping and winds increasing. Thus it might be expected that allochthonous material would enter the ponds on a random basis; and growth rates be temperature dependent.

### TABLE 3-11

### N/P RATIOS IN POND ASSAYS
(values in mg/mg)

| Pond No. | Based on Total Inorganic-N and $PO_4$-P | | | | | |
|---|---|---|---|---|---|---|
| | Assay Number (See Table 2-1, Chapter II) | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | 5.2 | 6.1 | 5.7 | 15.5 | 27.2 | 41.2 |
| 6 | 8.8 | 2.0 | 1.9 | 3.2 | 14.0 | 38.9 |
| 3 | 2.4 | 3.7 | 3.4 | 9.6 | 106.1 | 43.3 |
| 7 | 2.9 | 3.3 | 3.2 | 29.7 | 15.8 | 25.6 |
| 4 | 1.0 | 2.2 | 2.6 | 12.1 | 41.3 | 48.1 |
| 8 | 1.0 | 2.1 | 2.4 | 8.4 | 19.8 | 126.4 |
| | Based on Soluble $NH_3$-N and $PO_4$-P | | | | | |
| 2 | 3.8 | 3.9 | 7.4 | 22.5 | 27.4 | 40.3 |
| 6 | 7.9 | 2.2 | 1.2 | 5.1 | 12.2 | 38.4 |
| 3 | 7.2 | 5.6 | 5.7 | 8.6 | 103.5 | 45.2 |
| 7 | 8.1 | 4.5 | 4.3 | 28.3 | 15.3 | 24.4 |
| 4 | 4.2 | 3.6 | 6.3 | 13.0 | 44.3 | 55.5 |
| 8 | 3.6 | 3.4 | 4.5 | 8.9 | 23.0 | 137.1 |

## Materials Inventory

The term "inventory" rather than materials balance has been used herein because of the difficulties of making a complete mass balance in outdoor pond assays. However, the general expectation that decreases in nutrients should be reflected in an increase in volatile suspended solids can be tested from the data presented in the foregoing tables and an estimate of the nitrogen content of living cells. To this end Table 3-12 was prepared from data presented in Table 3-4 (VSS) and Table 3-7 (Inorganic-N) by assuming that the observed loss in N is entirely bound up in the observed gain in VSS.

The possiblity that iron, or such trace elements Mg, Zn, Cu, Co, B, and Mo, might be limiting was explored in Ponds 4 and 8. In Assays 1, 2, and 3, LTW was fortified with iron and trace elements in addition to ammonia-N and $PO_4$. During Assays 4, 5, and 6, Ponds 4 and 8 contained LTW and 1% tertiary effluent, plus iron and trace elements (see Table A-1, Appendix A). An examination of Table 3-4 shows an apparent small difference between Ponds 7,3 and 8,4 in Assays 4 and 5, but none in Assay 6. In view of the variations evident throughout other assays it cannot be concluded from the data that trace elements or iron significantly affected the growth rate of biomass as measured by VSS.

## TABLE 3-12

## CALCULATED PERCENT INORGANIC-N IN VSS

| Pond No. | Assay Number | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | 4.5 | 3.9 | 7.4 | 15.5 | 14.2 | 6.5 |
| 6 | 7.9 | 2.2 | 1.2 | - | 4.6 | 3.9 |
| 3 | 7.2 | 5.6 | 5.7 | 6.3 | 4.7 | 4.5 |
| 7 | 8.1 | 4.5 | 4.3 | 57.2[a] | 24.4[a] | 6.4 |
| 4 | 4.2 | 3.6 | 6.3 | 6.1 | 9.8 | 4.6 |
| 8 | 3.6 | 3.4 | 4.5 | 9.2 | 4.1 | 5.1 |

[a] Value uncertain due to operational problem in Pond 7.

The nitrogen content of various algae as summarized in the Second Progress Report [1] range from approximately 4 to 11 percent, although some species may be appreciably lower and luxury uptake of nitrogen in nitrogen-rich media may lead to higher values. A mass balance of nitrogen made on ponds during assays in 1968-1969 by the authors of this report indicated about 10 percent nitrogen in organisms indigenous to Lake Tahoe on the basis of nitrogen vs VSS. Other observations of Scenedesmus and Chlorella by the authors show 6 to 8 percent nitrogen on a dry weight basis. Whipple [9] reported the nitrogen content of Diatomaceae to be 3.66 percent. From such general information the data in Table 3-12 might be said to indicate a reasonably good materials balance in the nutrient — VSS conversion; and hence that reasonable confidence in the overall results of the inventory is justified.

## BIOLOGICAL UTILIZATION OF NUTRIENTS

### Introduction

From the inventory of quality factors summarized in Tables 3-4 to 3-12 it has been shown that nitrogen and phosphorus compounds were converted into volatile suspended solids (VSS) during the pond assays. To evaluate the algal growth stimulation associated with such utilization of nutrients, growth rates and cell biomass measurements were made and analyzed. Because indigenous organisms rather than a single test alga were necessarily involved in pond assays, increase in VSS was taken as the measure of biomass instead of the cell count found suitable in flask assays of LTW (Table 3-2).

Initial and final concentrations of nutrients, VSS, and other water quality factors are summarized in Tables C-1 and D-1 (Appendix C and Appendix D). On the basis of the previous year's experience [1] the ponds were considered to be operating at steady state after about three residence periods under constant operating conditions, hence such a criterion was used in preparing ponds for the 3-, 5-, and 8-day assays scheduled as outlined in Table 2-1, Chapter II.

## Comparison of Ponds

At steady state the biomass levels in duplicate ponds should theoretically be the same. An analysis of variance for paired ponds for the six assays is presented in Table 3-13. It shows, as did the inventory of quality factors, that this ideal situation did not pertain. The differences are probably the result of such factors as physical location, which allowed more wind transported allochthonous material to collect in one replicate than in the other; experimental error due to flow rate variation; and variation in influent characteristics during the course of the assay. Nevertheless, most replicate assays did not differ significantly at the 95 percent confidence level. Those that did differ significantly from each other at $P > 0.95$ are underscored in Table 3-13.

## Pond Assays of Lake Tahoe Water (LTW)

Mean values of biomass in terms of VSS at steady state in pond assays of LTW are summarized in Columns 2 and 3 of Table 3-13. None of the VSS values in the table differ statistically between assays, although differences appeared between replicate ponds in Assays 1 and 4. Consequently it appears that light and temperature were not the factors which limited growth of organisms (mostly pennate diatoms) comprising the biomass, although water temperatures approached critical lower limits during Assays 4, 5, and 6. That nutrients were the limiting factor may be correctly inferred from Table 3-11, which shows that either N or P was limiting in all pond assays even when nutrients were added. As previously discussed in relation to this table, N/P ratios for LTW (Ponds 1 and 5) proved meaningless because the small concentrations of nutrients present were below the resolving power of the inventory technique, resulting in both positive and negative values. However, previous work on pond assays [1] of LTW led to the conclusion that the lake water is nitrogen limited. This conclusion is further verified by computations based on analytical data presented in Table C-1, Appendix C, which shows that during the assay period the Lake Tahoe water averaged 6.7/1 in the N/P ratio, which by the 10/1 criterion would place it in the nitrogen limited category.

## Kinetic Analysis

The chemical composition of water and effluents entering into the pond assays are presented in Table C-1, Appendix C. Similar data describing the changes occurring in all ponds during all assays are presented in Table D-1, Appendix D. In this table the values shown for VSS unavoidably include extraneous (allochthonous) organic noncellular material which could not be excluded by skimming of the pond surface. Consequently, because increase in VSS is the measure of both growth rate and total productivity of the ponds, it was necessary to make such corrections as possible for extraneous organic matter. To accomplish this, a correction factor was developed by making a VSS analysis of samples from a control pond containing only LTW and allochthonous material. By assuming that the allochthonous material was the same in all ponds, a "net volatile suspended solids" value was obtained by subtracting the correction factor from the observed VSS in each pond. Net VSS data were used in kinetic analyses of pond data. However, as a check the unadjusted VSS data were also subjected to kinetic analysis of each pond, as were observed VSS data (Table D-1) corrected for influent VSS in LTW and in effluent added to increase nutrients.

In evaluating the results of kinetic analyses which follow, and particularly in comparing them with those reported in the Second Progress Report [1], it should be borne in mind that the data herein analyzed are much more refined and accurate than those of the previous year, as is borne out in the VSS materials balance presented in a subsequent section.

For data processing purposes a number of simplifying assumptions had to be made to put all of the data in a foremat for processing with a digital computer. Computer programs were then written for nitrogen as the growth limiting nutrient

# TABLE 3-13

## COMPARISON OF BIOMASS ESTIMATES BETWEEN PONDS RECEIVING THE SAME INFLUENTS

| Assay No. | Mean Biomass Value[a], mg/ℓ VSS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LTW | | 0.1% II | | 1.0% II | | 1.0% S-II | | 2.0% III | | 1.0% III | | 1.0% III+TE | |
| | 1 | 5 | 2 | 6 | 3 | 7 | 4 | 8 | 2 | 6 | 3 | 7 | 4 | 8 |
| 1 | $\underline{0.91}$ | $\underline{0.79}$[b] | 1.39 | 1.29 | 5.17 | 5.12 | 4.88 | 5.31 | - | - | - | - | - | - |
| 2 | 0.77 | 0.71 | 1.29 | 1.09 | 6.30 | 6.72 | 5.66 | 6.50 | - | - | - | - | - | - |
| 3 | 0.66 | 0.58 | 0.91 | 1.36 | $\underline{4.65}$ | $\underline{5.62}$ | $\underline{3.23}$ | $\underline{4.46}$ | - | - | - | - | - | - |
| 4 | $\underline{0.84}$ | $\underline{0.57}$ | - | - | - | - | - | - | 1.14 | 1.10 | $\underline{1.14}$ | $\underline{0.63}$ | 1.24 | 1.16 |
| 5 | 0.86 | 0.84 | - | - | - | - | - | - | 1.48 | 2.17 | $\underline{1.42}$ | $\underline{0.95}$ | 1.46 | 1.64 |
| 6 | 0.87 | 0.74 | - | - | - | - | - | - | $\underline{3.79}$ | $\underline{4.81}$ | 1.74 | 1.90 | 1.84 | 1.75 |

[a] II is secondary effluent, S-II is simulated secondary effluent prepared by adding macronutrients, iron, and trace elements in excess plus $NH_3$-N and $PO_4$-P equivalent to the concentration measured in the secondary effluent (see Table A-1 in Appendix A), III is tertiary effluent, III + TE is tertiary effluent with quantities of iron and essential trace elements added (see Table A-1 in Appendix A).

[b] Underscored values indicate that replicate ponds were significantly different at $P > 0.95$.

and for phosphorus as the limiting nutrient, as well as for the cell continuity equation. In this manner machine methods could be used to compute rate constants and coefficients as well as correlation coefficients.

The most important assumptions included the concept that steady state in a pond was achieved within three residence periods; that VSS yields a good estimate of cell concentration ($X_1$) in the ponds; and that the soluble forms of nutrients represent the actual pond nutrient concentration ($S_1$).

For kinetic analysis, pond data were grouped according to limiting nutrient as determined by the N/P ratio, Table 3-11. Thus Assays 1, 2, and 3 of secondary effluent at residence periods ($\theta$) of 3, 5, and 8 days were grouped as nitrogen limited assays; and Assays 4, 5, and 6 of tertiary effluent at all residence periods constituted the phosphorus limited group.

Kinetic-cell materials balance equations used in statistical analysis of the data were those developed in detail in the 1968-1969 Report [1] (cell continuity or cell conservation equation; and kinetic equation). In their final form these equations are:

$$\frac{1}{\theta_c} = \mu - k_d = Yq - k_d = \frac{Y(S_o - S_1)}{X_1\theta} - k_d \qquad (1)$$

and

$$\frac{1}{\mu} = \frac{1}{Yq} = \frac{K_s}{\hat{\mu}}\left(\frac{1}{S_1}\right) + \frac{1}{\hat{\mu}} \qquad (2)$$

In which:

$q$ = specific nutrient removal velocity

$$\frac{\text{gms nutrient removed}}{\text{gms cells} - \text{day}} \ (\text{day}^{-1})$$

$\mu$ = specific growth rate $\left(\frac{\text{gms cells produced}}{\text{gm cells} - \text{day}}\right)$, time$^{-1}$

$S_o$ = influent concentration of rate limiting nutrient

$S_1$ = concentration of rate limiting nutrient in the reaction system

$X_1$ = concentration of cells in reaction system

$\theta$ = hydraulic residence time of system, i.e., $\theta = V/F$

$\theta_c$ = cellular residence time (i.e., mean cell age in system)

$\frac{1}{\theta_c}$ = net cellular growth rate

$k_d$ = specific decay rate i.e., $\left(\frac{\text{gms cells destroyed}}{\text{gm cells} - \text{day}}\right)$

$Y$ = yield coefficient i.e., $\left(\frac{\text{gms cells produced}}{\text{gm nutrient removed}}\right)$

$\hat{\mu}$ = maximum specific growth rate, time$^{-1}$

$K_s$ = nutrient concentration at one-half the maximum specific growth rate, mass per unit volume.

A computer program was written to determine the rate constants and coefficients in Equations 1 and 2 for each of the two groups of assays, considering each of the following nutrients or combinations of nutrients which might be important: $NO_3$-N, $NH_3$-N, Inorganic N, ($NO_3$-N + $NH_3$-N), Total N, $PO_4$-P, and Total P. The three estimates of cell mass based on VSS (see page 39) were analyzed with each of the nutrients. The data from replicate assays were then combined and also analyzed for each form of nitrogen and phosphorus, using the same three VSS estimates of cell mass. Thus a total of 72 sets consisting of 387 values for each of the rate constants and coefficients were determined for ponds receiving either secondary or tertiary effluent.

## Kinetic Constants and Coefficients for Secondary Effluents

Tables 3-14 and 3-15 report a summary of the kinetic constants and coefficients for Pond Assays 1, 2, and 3 of secondary sewage treatment plant effluents. Evidence previously presented in Table 3-11 indicates that the growth rate in all of these cases was limited by the concentration of available inorganic nitrogen. To check this conclusion, tables similar to 3-14 and 3-15 were prepared for all forms of nitrogen and phosphorus reported in Table C-1, Appendix C. From an examination of these tables it was calculated that inorganic nitrogen and $PO_4$-P appeared to control growth response. Therefore only these two factors are herein discussed in detail.

In preparing Tables 3-14 and 3-15 the data were first analyzed on the assumption that the gross VSS (volatile suspended solids) is a measure of the biomass produced in individual ponds during any residence period — 3, 5, or 8 days. The data from replicate ponds were then combined for analysis under the same assumption. Results obtained from individual and combined ponds, assuming inorganic nitrogen to be limiting, are reported in the first two sections of Table 3-14; and in similar sections of Table 3-15, assuming $PO_4$-P to be the growth rate limiting nutrient.

A second set of analyses was made on the assumption that biomass was measured by gross VSS minus VSS in the influent to the ponds. The results for both individual and combined replicate ponds, and for inorganic nitrogen and $PO_4$-P, are likewise reported in the tables.

Finally, the analysis was repeated once more assuming that VSS minus the influent and the allochthonous material in Lake Tahoe water reference ponds measured the biomass attained during pond assays. Although this last approach is theoretically most nearly correct, the possibility is entertained that it may be an unnecessary refinement under the outdoor conditions of pond assay, and that in comparison with other assumptions something may be learned of the accuracy of the data.

Examination of Table 3-14 shows that the statistical fit of the materials balance equation for the individual ponds for Assays 1-3 gave statistically significant correlation coefficients ($r_1$ at 95% level) in all but two instances (Ponds 1 and 6) when the gross VSS was used as the estimate of biomass. When the replicate ponds for 1 and 6 were combined, all four sets of data yielded correlation coefficients significant at the 95% level. In comparison, the results obtained with the other two methods of estimating biomass showed a decline in the correlation coefficients. However, the number of statistically significant correlation coefficients remained the same for both individual ponds and the combined replicates. This indicates that attempts to refine the biomass measurement when assessed as VSS by correcting for influent VSS and allochthonous material at such low concentrations of suspended material is unnecessary.

The correlation coefficients ($r_2$) for the Michaelis-Menten (M-M) kinetic equation were statistically significant for only the combined ponds (3 and 7) containing 1% secondary effluent and the individual Pond No. 5 containing Lake Tahoe water. When the Lake Tahoe water replicates were combined, the Lake Tahoe water

TABLE 3-14

SUMMARY OF RATE CONSTANTS AND COEFFICIENTS FOR POND REACTORS ASSUMING RATE LIMITING NUTRIENT TO BE INORGANIC NITROGEN ($NO_3 + NO_2 + NH_3$) FOR ASSAYS 1-3

| Pond No. and Influent | No. of Data Points | Biomass Estimate Used | $\mu = \hat{\mu} S_1/K_s + S_1$ | | | $1/\theta_c \cong \frac{1}{\theta} = \mu - k_d = Yq - k_d$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | $\hat{\mu}$ $day^{-1}$ | $K_s$ µg/ℓ | $r_2$ | Y mg VSS/mg | $k_d$ $day^{-1}$ | $r_1$ |
| 1 LTW | 9 | Gross VSS<br>($X_1$) | 0.01 | 15.0 | - 0.40 | 16.6 | - 0.170 | 0.53 |
| 5 LTW | 10 | | - 0.03 | - 48.3 | 0.69 | 23.7 | - 0.117 | 0.84 |
| 2 II | 15 | | - 0.03 | - 72.9 | 0.40 | 17.4 | - 0.111 | 0.87 |
| 6 II | 13 | | 0.05 | 24.4 | 0.34 | 11.3 | - 0.157 | 0.39 |
| 3 II | 17 | | 0.13 | 10.9 | 0.38 | 14.2 | - 0.064 | 0.97 |
| 7 II | 17 | | 0.16 | 11.0 | 0.42 | 17.5 | - 0.049 | 0.94 |
| 4 S-II | 15 | | 0.11 | 9.5 | 0.19 | 11.7 | - 0.087 | 0.94 |
| 8 S-II | 15 | | 0.13 | 4.5 | 0.20 | 18.0 | - 0.061 | 0.96 |
| 1, 5 LTW | 19 | | 0.03 | 1.8 | 0.02 | 20.6 | - 0.142 | 0.70 |
| 2, 6 II | 28 | | 0.11 | 113.0 | 0.26 | 15.1 | - 0.131 | 0.65 |
| 3, 7 II | 34 | | 0.14 | 11.0 | 0.40 | 15.3 | - 0.060 | 0.94 |
| 4, 8 S-II | 30 | | 0.11 | 6.4 | 0.21 | 13.2 | - 0.086 | 0.92 |
| 1 LTW | 9 | VSS Corrected for Influent VSS<br>($X_1 - X_0$) | 0.01 | - 15.4 | - 0.34 | 7.0 | - 0.183 | 0.35 |
| 5 LTW | 10 | | - 0.16 | - 146.4 | 0.53 | 7.9 | - 0.137 | 0.60 |
| 2 II | 15 | | - 0.04 | - 86.7 | 0.39 | 11.8 | - 0.113 | 0.86 |
| 6 II | 13 | | 0.03 | 9.2 | 0.20 | 5.8 | - 0.169 | 0.25 |
| 3 II | 17 | | 0.14 | 10.3 | 0.38 | 13.4 | - 0.060 | 0.96 |
| 7 II | 17 | | 0.16 | 8.5 | 0.36 | 16.8 | - 0.042 | 0.92 |
| 4 S-II | 15 | | 0.10 | 4.5 | 0.10 | 10.4 | - 0.088 | 0.93 |
| 8 S-II | 15 | | 0.13 | 3.4 | 0.17 | 16.6 | - 0.060 | 0.94 |
| 1, 5 LTW | 19 | | 0.01 | - 11.6 | - 0.18 | 6.9 | - 0.164 | 0.46 |
| 2, 6 II | 28 | | 0.07 | 49.9 | 0.22 | 10.6 | - 0.133 | 0.61 |
| 3, 7 II | 34 | | 0.14 | 9.4 | 0.38 | 14.5 | - 0.056 | 0.93 |
| 4, 8 S-II | 30 | | 0.10 | 4.6 | 0.16 | 11.7 | - 0.088 | 0.89 |
| 2 II | 15 | VSS Corrected for Influent VSS and LTW Reference Ponds<br>$(X_1 - X_0)_p$ -<br>$(X_1 - X_0)_{Mean\ LTW}$ | - 0.03 | - 101.2 | 0.38 | 4.0 | - 0.138 | 0.83 |
| 6 II | 13 | | 0.00 | 0.3 | 0.01 | - 0.3 | - 0.210 | - 0.03 |
| 3 II | 17 | | 0.14 | 10.4 | 0.38 | 12.2 | - 0.062 | 0.95 |
| 7 II | 17 | | 0.16 | 8.1 | 0.35 | 15.6 | - 0.043 | 0.91 |
| 4 S-II | 15 | | 0.09 | 3.7 | 0.08 | 8.9 | - 0.093 | 0.92 |
| 8 S-II | 13 | | 0.13 | 3.2 | 0.16 | 14.9 | - 0.064 | 0.94 |
| 2, 6 II | 28 | | 0.03 | 28.1 | 0.17 | 3.3 | - 0.157 | 0.52 |
| 3, 7 II | 34 | | 0.14 | 9.2 | 0.37 | 13.3 | - 0.058 | 0.92 |
| 4, 8 II | 30 | | 0.09 | 4.4 | 0.16 | 10.1 | - 0.094 | 0.81 |

## TABLE 3-15

## SUMMARY OF RATE CONSTANTS AND COEFFICIENTS FOR POND REACTORS ASSUMING PHOSPHATE ($PO_4^{\equiv}$-P) TO BE THE LIMITING NUTRIENT FOR ASSAYS 1-3

| Pond No. and Influent | No. of Data Points | Biomass Estimate Used | $\mu = \hat{\mu} S_1/K_s + S_1$ | | | $1/\theta_c \approx \frac{1}{\theta} = \mu - k_d = Yq - k_d$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | $\hat{\mu}$ day$^{-1}$ | $K_s$ μg/ℓ | $r_2$ | Y mg VSS/mg | $k_d$ day$^{-1}$ | $r_1$ |
| 1 LTW | 7 | Gross VSS ($X_1$) | 0.07 | - 0.1 | - 0.06 | 242.6 | - 0.104 | 0.78 |
| 5 LTW | 7 | | 0.07 | - 0.3 | - 0.07 | 278.6 | - 0.112 | 0.89 |
| 2 II | 15 | | 0.10 | 0.3 | 0.03 | 106.7 | - 0.062 | 0.89 |
| 6 II | 15 | | 0.05 | - 0.8 | - 0.14 | 60.4 | - 0.125 | 0.56 |
| 3 II | 17 | | 0.32 | 16.5 | 0.59 | 61.9 | - 0.017 | 0.84 |
| 7 II | 17 | | 0.25 | 4.4 | 0.42 | 77.6 | + 0.015 | 0.82 |
| 4 S-II | 15 | | 0.06 | - 5.1 | - 0.20 | 27.6 | - 0.090 | 0.93 |
| 8 S-II | 15 | | 0.13 | 2.0 | 0.10 | 42.6 | - 0.059 | 0.95 |
| 1, 5 LTW | 14 | | 0.08 | 0.1 | 0.04 | 262.8 | - 0.107 | 0.83 |
| 2, 6 II | 30 | | 0.07 | - 0.3 | - 0.04 | 81.9 | - 0.096 | 0.72 |
| 3, 7 II | 34 | | 0.25 | 6.9 | 0.47 | 67.3 | - 0.007 | 0.82 |
| 4, 8 S-II | 30 | | 0.09 | 0.5 | 0.02 | 31.5 | - 0.086 | 0.91 |
| 1 LTW | 7 | VSS Corrected for Influent VSS ($X_1 - X_o$) | - 0.01 | 0.4 | - 0.16 | - 9.82 | - 0.218 | - 0.12 |
| 5 LTW | 7 | | 0.00 | - 0.6 | 0.13 | - 6.30 | - 0.244 | - 0.06 |
| 2 II | 15 | | 0.07 | - 1.4 | - 0.16 | 68.1 | - 0.063 | 0.80 |
| 6 II | 15 | | 0.02 | - 2.0 | - 0.41 | 26.5 | - 0.152 | 0.32 |
| 3 II | 17 | | 0.30 | 12.7 | 0.52 | 57.4 | - 0.012 | 0.80 |
| 7 II | 17 | | 0.27 | 4.8 | 0.48 | 70.9 | + 0.017 | 0.76 |
| 4 S-II | 15 | | 0.06 | - 5.6 | - 0.24 | 24.5 | - 0.091 | 0.91 |
| 8 S-II | 15 | | 0.14 | 2.2 | 0.11 | 39.4 | - 0.058 | 0.93 |
| 1, 5 LTW | 14 | | - 0.01 | 0.2 | - 0.06 | - 7.87 | - 0.231 | - 0.09 |
| 2, 6 II | 30 | | 0.05 | - 1.7 | - 0.25 | 47.5 | - 0.107 | 0.57 |
| 3, 7 II | 34 | | 0.25 | 6.6 | 0.48 | 61.7 | - 0.004 | 0.77 |
| 4, 8 S-II | 30 | | 0.09 | 0.6 | 0.03 | 28.0 | - 0.088 | 0.88 |
| 2 II | 15 | VSS Corrected for Influent VSS and LTW Reference Ponds $(X_1 - X_o)_P - (X_1 - X_o)_{Avg. LTW}$ | 0.03 | - 1.9 | - 0.19 | 18.2 | - 0.119 | - 0.70 |
| 6 II | 15 | | 0.00 | - 2.5 | 0.46 | - 2.3 | - 0.215 | - 0.07 |
| 3 II | 17 | | 0.28 | 12.5 | [illegible] | 52.1 | - 0.015 | 0.79 |
| 7 II | 17 | | 0.26 | 5.0 | 0.50 | 64.7 | + 0.012 | 0.74 |
| 4 S-II | 15 | | 0.06 | - 5.7 | - 0.24 | 21.1 | - 0.096 | 0.90 |
| 8 S-II | 15 | | 0.14 | 2.5 | 0.12 | 35.3 | - 0.063 | 0.92 |
| 2, 6 II | 30 | | 1.37 | - 2.2 | - 0.29 | 9.9 | - 0.160 | 0.35 |
| 3, 7 II | 34 | | 0.25 | 6.7 | 0.48 | 55.8 | - 0.009 | 0.76 |
| 4, 8 II | 30 | | 0.09 | 0.8 | 0.04 | 24.0 | - 0.094 | 0.87 |

assays did not yield statistically significant results. The results for the 1% secondary effluent assays (Ponds 3 and 7) were statistically significant when all three methods of expressing biomass were employed, but as noted for the materials balance equation, there was a decline in the correlation as attempts were made to refine the biomass data.

Tables 3-14 and 3-15 show that except for Lake Tahoe water (Ponds 1 and 5) reasonable values are obtained for the kinetic coefficients. There is very good agreement between the individual values of maximum growth rate, yield, and the decay rate when all of the possible sources of error are considered. In general, the 1% secondary (Ponds 3 and 7) and 1% simulated secondary effluents (Ponds 4 and 8) gave similar kinetic coefficients. However, the correlation coefficients for the analysis of the separate and combined replicates for simulated secondary effluents using the M-M equation were not statistically significant. These results are surprising in view of the better control expected and usually attained with a synthetic nutrient. Perhaps the simulated secondary effluent was deficient in some basic stimulating factor.

Only six positive decay rate coefficients were obtained out of the 387 individual and combined analyses performed, and these occurred in the same pond regardless of the method of biomass estimation. When data on this pond were combined with those of its replicate, the decay rate became negative. As reported in the Second Progress Report [1] negative decay rates are not uncommon in algal assays although theoretically negative decay rates are not rational.

When phosphate was assumed to be the limiting nutrient in Assays 1-3 (Table 3-15), the materials balance and M-M equations were comparable with the results obtained when inorganic nitrogen was assumed to be the limiting nutrient. Reasonable estimates of the various parameters as well as estimates of the composition of biomass for diatoms were obtained [1].

Based upon the gross VSS estimates of the biomass (Y) and excluding the results of the reference ponds containing only Lake Tahoe water, the composition of the organisms in the ponds corresponding to the reported Y values averages 6.7% nitrogen and 1.7% phosphorus when grown in Lake Tahoe water plus both secondary and simulated secondary effluents.

Based on the general observation that algal cells normally contain nitrogen at 8 or 10 times their phosphorus content, the data indicate that the assays of secondary effluent in Lake Tahoe water were limited by nitrogen in the amount of VSS which might have been produced with the available phosphorus.

It is interesting to note that the simulated secondary effluent (Ponds 4 and 8) produced biomass that contained 6.6% nitrogen but only half of the 1.7% P noted in Ponds 3 and 7. This would indicate that a different biota was involved in the two cases although the biomass was essentially the same. Inasmuch as there are factors in sewage effluents, resulting from the normal growth-decay cycle of organic matter, which influence biological growth, this is not surprising. That a different biota did indeed exist is supported by visual observation of the ponds during the assays reported. Ponds 3 and 7 were dark green in color, whereas Ponds 4 and 8 were of a much paler hue.

### Kinetic Constants and Coefficients for Tertiary Effluents

Kinetic constants and coefficients computed for Assays 4, 5, and 6 of tertiary effluents are summarized in Tables 3-16 and 3-17. Data previously presented in Table 3-11 led to the conclusion that these assays were growth limited by phosphorus rather than by nitrogen. The general approach and rationale of analysis applied to tertiary effluent data is as described in the preceding section dealing with secondary effluents.

TABLE 3-16

SUMMARY OF RATE CONSTANTS AND COEFFICIENTS FOR POND REACTORS ASSUMING INORGANIC NITROGEN ($NO_2$ + $NO_3$ + $NH_3$-N) TO BE THE LIMITING NUTRIENT FOR ASSAYS 4-6

| Pond No. and Influent | No. of Data Points | Biomass Estimate Used | $\mu = \hat{\mu} S_1/K_s + S_1$ | | | $1/\theta_c \approx \frac{1}{\theta} = \mu - k_d = Y_q - k_d$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | $\hat{\mu}$ day$^{-1}$ | $K_s$ µg/ℓ | $r_2$ | Y mg VSS/mg | $k_d$ day$^{-1}$ | $r_1$ |
| 1 LTW | 7 | Gross VSS ($X_1$) | - 0.07 | 2.8 | - 0.11 | - 36.4 | - 0.317 | - 0.55 |
| 5 LTW | 8 | | - 0.03 | - 1.0 | 0.08 | - 15.0 | - 0.247 | - 0.31 |
| 2 III | 10 | | 0.04 | - 48.2 | - 0.04 | 6.4 | - 0.161 | 0.37 |
| 6 III | 9 | | 0.00 | - 181.0 | - 0.28 | 4.4 | - 0.203 | 0.20 |
| 3 III | 8 | | - 0.32 | - 823.6 | 0.35 | 6.3 | - 0.131 | 0.37 |
| 7 III | 8 | | - 0.02 | - 90.1 | 0.49 | - 9.0 | - 0.320 | - 0.61 |
| 4 III + TE | 8 | | - 0.04 | - 12.7 | 0.09 | - 8.0 | - 0.278 | - 0.22 |
| 8 III + TE | 9 | | 0.11 | 186.6 | 0.17 | 7.2 | - 0.152 | 0.28 |
| 1, 5 LTW | 15 | | - 0.04 | - 0.5 | 0.04 | - 23.8 | - 0.279 | - 0.43 |
| 2, 6 III | 19 | | 0.00 | - 179.2 | - 0.27 | 4.7 | - 0.189 | 0.26 |
| 3, 7 III | 16 | | - 0.01 | - 64.2 | 0.26 | - 3.1 | - 0.239 | - 0.20 |
| 4, 8 III + TE | 17 | | 0.01 | - 21.7 | 0.06 | 2.1 | - 0.201 | 0.07 |
| 1 LTW | 5 | VSS Corrected for Influent VSS ($X_1$ - $X_0$) | - 0.06 | 1.7 | - 0.09 | - 28.0 | - 0.328 | - 0.57 |
| 5 LTW | 7 | | 0.00 | 2.6 | - 0.10 | - 0.7 | - 0.216 | - 0.14 |
| 2 III | 10 | | - 0.01 | - 48.3 | 0.04 | - 0.8 | - 0.246 | - 0.11 |
| 6 III | 9 | | 0.00 | - 181.3 | - 0.31 | 0.5 | - 0.230 | 0.03 |
| 3 III | 8 | | 0.01 | 65.1 | 0.09 | 0.4 | - 0.188 | 0.04 |
| 7 III | 6 | | - 0.01 | - 102.8 | 0.51 | - 5.6 | - 0.326 | - 0.54 |
| 4 III + TE | 8 | | - 0.01 | - 49.0 | 0.36 | - 1.4 | - 0.241 | - 0.18 |
| 8 III + TE | 9 | | 0.03 | 87.3 | 0.22 | 1.5 | - 0.193 | 0.09 |
| 1, 5 LTW | 12 | | 0.00 | 1.6 | - 0.07 | - 1.3 | - 0.238 | - 0.22 |
| 2, 6 III | 19 | | 0.00 | - 180.4 | 0.30 | - 0.5 | - 0.240 | - 0.07 |
| 3, 7 III | 14 | | - 0.01 | - 80.9 | 0.37 | - 2.7 | - 0.260 | - 0.26 |
| 4, 8 III + TE | 17 | | - 0.01 | - 30.9 | 0.18 | - 0.7 | - 0.226 | - 0.07 |
| 2 III | 10 | VSS Corrected for Influent VSS and LTW Reference Ponds $(X_1 - X_0)_P$ - $(X_1 - X_0)_{Avg.\ LTW}$ | - 0.01 | - 90.4 | 0.06 | - 0.7 | - 0.252 | - 0.25 |
| 6 III | 9 | | - 0.01 | - 204.9 | 0.56 | - 5.3 | - 0.298 | - 0.37 |
| 3 III | 8 | | 0.01 | - 88.4 | - 0.43 | 0.6 | - 0.189 | 0.23 |
| 7 III | 6 | | 0.00 | - 109.6 | 0.55 | - 1.0 | - 0.294 | - 0.56 |
| 4 III + TE | 8 | | 0.00 | - 79.5 | 0.64 | - 0.3 | - 0.225 | - 0.83 |
| 8 III + TE | 9 | | - 0.01 | - 58.1 | 0.23 | - 0.5 | - 0.220 | - 0.12 |
| 2, 6 III | 19 | | 0.00 | - 19.5 | 0.45 | - 0.8 | - 0.249 | - 0.22 |
| 3, 7 III | 14 | | 0.00 | - 10.0 | 0.54 | - 0.2 | - 0.221 | - 0.10 |
| 4, 8 III + TE | 17 | | 0.00 | - 7.7 | 0.50 | - 0.4 | - 0.222 | - 0.11 |

## TABLE 3-17

## SUMMARY OF RATE CONSTANTS AND COEFFICIENTS FOR POND REACTORS ASSUMING PHOSPHATE ($PO_4^{\equiv}$-P) TO BE THE LIMITING NUTRIENT FOR ASSAYS 4-6

| Pond No. and Influent | No. of Data Points | Biomass Estimate Used | $\mu = \hat{\mu} S_1/K_s + S_1$ | | | $1/\theta_c \approx \frac{1}{\theta} = \mu - k_d = Yq - k_d$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | $\hat{\mu}$ day$^{-1}$ | $K_s$ µg/ℓ | $r_2$ | Y mg VSS/mg | $k_d$ day$^{-1}$ | $r_1$ |
| 1 LTW | 6 | Gross VSS $(X_1)$ | - 0.02 | - 0.1 | - 0.06 | - 72.3 | - 0.213 | - 0.24 |
| 5 LTW | 4 | | - 0.22 | 0.5 | - 0.65 | - 190.1 | - 0.384 | - 0.84 |
| 2 III | 10 | | - 0.02 | - 0.1 | 0.91 | - 59.0 | - 0.259 | - 0.20 |
| 6 III | 10 | | - 0.05 | 0.1 | - 0.06 | - 192.2 | - 0.307 | - 0.54 |
| 3 III | 9 | | 0.07 | - 6.7 | - 0.28 | - 146.3 | - 0.269 | - 0.40 |
| 7 III | 10 | | 0.02 | - 4.4 | - 0.43 | - 70.1 | - 0.248 | - 0.33 |
| 4 III + TE | 9 | | 0.00 | - 0.2 | 0.12 | - 3.3 | - 0.221 | - 0.01 |
| 8 III + TE | 9 | | - 0.04 | 0.2 | - 0.11 | - 156.5 | - 0.280 | - 0.41 |
| 1, 5 LTW | 10 | | - 0.03 | 0.1 | - 0.07 | - 65.2 | - 0.230 | - 0.35 |
| 2, 6 III | 20 | | - 0.03 | 0.0 | 0.01 | - 110.0 | - 0.279 | - 0.35 |
| 3, 7 III | 19 | | 0.03 | - 5.0 | - 0.36 | - 85.8 | - 0.251 | - 0.33 |
| 4, 8 III + TE | 18 | | - 0.02 | - 0.1 | 0.05 | - 80.1 | - 0.252 | - 0.21 |
| 1 LTW | 5 | VSS Corrected for Influent VSS $(X_1 - X_o)$ | - 0.15 | 10.8 | - 0.96 | - 57.0 | - 0.221 | - 0.34 |
| 5 LTW | 4 | | - 0.01 | - 0.4 | 0.36 | - 7.5 | - 0.242 | - 0.40 |
| 2 III | 10 | | - 0.02 | - 0.1 | 0.10 | - 47.3 | - 0.271 | - 0.35 |
| 6 III | 10 | | - 0.06 | 0.2 | - 0.12 | - 146.0 | - 0.315 | - 0.65 |
| 3 III | 9 | | 23.63 | - 1252.2 | - 0.18 | - 121.2 | - 0.288 | - 0.31 |
| 7 III | 7 | | 0.01 | - 3.5 | - 0.29 | - 28.7 | - 0.266 | - 0.31 |
| 4 III + TE | 9 | | - 0.01 | - 0.3 | 0.13 | - 50.5 | - 0.255 | - 0.20 |
| 8 III + TE | 9 | | - 0.07 | 0.5 | - 0.32 | - 135.9 | - 0.301 | - 0.53 |
| 1, 5 LTW | 9 | | 0.00 | 0.0 | - 0.02 | - 3.5 | - 0.199 | - 0.17 |
| 2, 6 III | 20 | | - 0.03 | 0.0 | - 0.02 | - 69.2 | - 0.280 | - 0.44 |
| 3, 7 III | 16 | | 0.05 | - 9.9 | - 0.20 | - 36.5 | - 0.252 | - 0.30 |
| 4, 8 III + TE | 18 | | - 0.03 | 0.0 | 0.01 | - 91.4 | - 0.279 | - 0.36 |
| 2 III | 10 | VSS Corrected for Influent VSS and LTW Reference Ponds $(X_1 - X_o)_P - (X_1 - X_o)_{Avg.\ LTW}$ | 0.00 | - 0.1 | 0.02 | - 5.2 | - 0.242 | - 0.22 |
| 6 III | 10 | | - 0.01 | 0.1 | - 0.50 | - 10.0 | - 0.249 | - 0.45 |
| 3 III | 9 | | - 0.01 | - 0.8 | 0.09 | - 13.0 | - 0.226 | - 0.21 |
| 7 III | 7 | | 0.01 | - 3.4 | - 0.32 | - 100.8 | - 0.249 | - 0.27 |
| 4 III + TE | 9 | | - 0.01 | - 0.3 | 1.13 | - 20.3 | - 0.247 | - 0.29 |
| 8 III + TE | 9 | | - 0.03 | 1.0 | 0.29 | - 26.1 | - 0.248 | - 0.42 |
| 2, 6 III | 20 | | - 0.01 | 0.1 | - 0.03 | - 7.7 | - 0.246 | - 0.34 |
| 3, 7 III | 16 | | - 0.01 | 0.1 | - 0.01 | - 10.8 | - 0.235 | - 0.23 |
| 4, 8 III + TE | 18 | | - 0.02 | 0.1 | - 0.04 | - 23.3 | - 0.248 | - 0.36 |

Examination of Tables 3-16 and 3-17 show that only one statistically significant correlation coefficient was obtained when fitting the data to both equations. This occurred in Pond No. 2 using gross VSS as biomass and fitting the M-M equation when phosphate was assumed to be limiting. When data for Pond No. 2 was combined with that for its replicate Pond No. 6, the correlation coefficient was no longer significant. All of the kinetic parameters are unreasonable as well. The wide deviation from theory cannot be explained by a lack of iron and trace elements as the same response was measured in the ponds containing tertiary effluents with these compounds added in excess. The next obvious course is to suspect the presence of some toxic substance in the tertiary effluent. However, close examination of the mean values of the gross biomass shown in Table 3-18 indicates that a toxic effect was not evident at the higher concentration of 2% where a greater effect on the growth response would be expected.

Table 3-19 shows the mean values for the steady state inorganic nitrogen concentrations ($S_1$) which indicate that adequate nitrogen was present in the tertiary effluents (Assays 4-6); but Table 3-20 showing the phosphate concentrations in tertiary effluent indicates that the limits of measurement had been reached. Apparently all of the data were collected in the flat regions of the nutrient and cell mass versus mean residence time curves for continuous flow systems as shown in Figure 3-14. Therefore, it should not be expected that the least square solution of the kinetic model would provide reasonable constants and coefficients for systems operating at the threshold concentration of the limiting nutrient.

From Tables 3-19 and 3-20 it is evident that at steady state values the N/P ratio was drastically beyond the level at which phosphate becomes limiting, as previously suggested from less refined inventory data analysis.

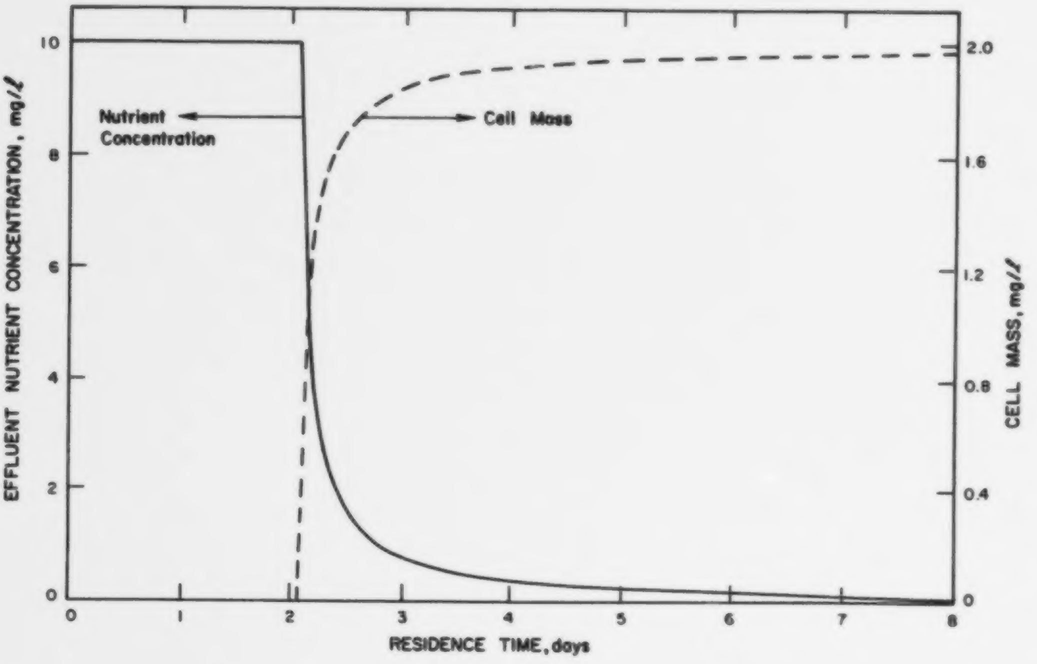

FIGURE 3-14. THEORETICAL STEADY-STATE CONDITIONS IN A SINGLE STAGE REACTOR

TABLE 5-18

MEANS OF BIOMASS ESTIMATES ATTAINED DURING STEADY-STATE OPERATION OF POND ASSAYS

| Pond No. / Assay No. and Residence Time | Mean and Coefficient of Variation of Biomass Estimates | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1[a] | | 5[a] | | 2[b] | | 6[b] | | 3[c] | | 7[c] | | 4[d] | | 8[d] | |
| | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) | Conc. mg/ℓ | Coef. Var. (%) |
| 1 (8 days) | 0.91 | 23.1 | 0.79 | 10.9 | 1.39 | 19.3 | 1.29 | 11.5 | 5.17 | 13.0 | 5.12 | 7.0 | 4.88 | 12.7 | 5.31 | 9.0 |
| 2 (5 days) | 0.77 | 13.8 | 0.71 | 18.0 | 1.29 | 16.6 | 1.09 | 17.4 | 6.30 | 14.7 | 6.72 | 10.3 | 5.66 | 18.8 | 6.50 | 9.1 |
| 3 (3 days) | 0.66 | 5.6 | 0.58 | 14.8 | 0.91 | 17.2 | 1.36 | 33.8 | 4.65 | 6.6 | 5.62 | 8.9 | 5.23 | 8.3 | 4.46 | 13.7 |
| 4 (8 days) | 0.84 | 15.0 | 0.57 | 26.5 | 1.14 | 7.3 | 1.10 | 30.6 | 1.14 | 12.8 | 0.63 | 53.3 | 1.24 | 18.9 | 1.16 | 25.5 |
| 5 (5 days) | 0.86 | 39.0 | 0.84 | 29.5 | 1.48 | 42.8 | 2.17 | 36.1 | 1.42 | 25.4 | 0.95 | 28.3 | 1.46 | 30.2 | 1.64 | 27.3 |
| 6 (3 days) | 0.87 | 28.8 | 0.74 | 29.2 | 3.79 | 16.1 | 4.81 | 17.0 | 1.84 | 24.5 | 1.75 | 5.1 | 1.74 | 14.5 | 1.90 | 21.4 |

[a] Lake Tahoe Water

[b] Assays 1-3 0.1% II, Assays 4-6 2% III

[c] Assays 1-3 1% II, Assays 4-6 1% III

[d] Assays 1-3 1% S-II, Assays 4-6 1% III plus TE

TABLE 5-19

MEANS OF INORGANIC NITROGEN ATTAINED DURING STEADY-STATE OPERATION OF POND ASSAYS

| Pond No. / Assay No. and Residence Time | Means and Coefficients of Variation of Inorganic Nitrogen ($NO_3$ + $NO_2$ + $NH_3$) CONCENTRATIONS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1[a] | | 5[a] | | 2[b] | | 6[b] | | 3[c] | | 7[c] | | 4[d] | | 8[d] | |
| | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) |
| 1 (8 days) | 39.2 | 58.2 | 24.6 | 65.1 | 31.8 | 77.5 | 30.5 | 50.3 | 40.2 | 68.2 | 29.1 | 54.0 | 27.3 | 36.3 | 42.0 | 64.0 |
| 2 (5 days) | 45.3 | 22.5 | 48.0 | 26.1 | 46.0 | 18.9 | 54.7 | 43.0 | 47.3 | 31.1 | 54.3 | 44.6 | 47.8 | 17.2 | 40.0 | 42.2 |
| 3 (3 days) | 39.3 | 60.4 | 34.7 | 49.5 | 42.0 | 41.4 | 52.3 | 39.5 | 60.0 | 72.0 | 49.3 | 52.3 | 44.3 | 45.6 | 42.7 | 38.3 |
| 4 (8 days) | 22.7 | 35.2 | 22.8 | 45.7 | 266.0 | 27.4 | 238.7 | 2.1 | 102.7 | 4.4 | 97.3 | 13.9 | 115.0 | 10.1 | 98.0 | 11.1 |
| 5 (5 days) | 35.1 | 54.7 | 29.8 | 42.0 | 243.2 | 35.3 | 289.7 | 10.1 | 166.0 | 23.7 | 170.8 | 16.2 | 156.3 | 27.2 | 154.7 | 20.3 |
| 6 (3 days) | 27.2 | 91.6 | 26.6 | 70.2 | 218.0 | 16.0 | 251.5 | 21.0 | 157.7 | 26.7 | 154.7 | 11.9 | 179.8 | 95.5 | 161.5 | 14.4 |

[a] Lake Tahoe Water

[b] Assays 1-3 0.1% II, Assays 4-6 2% III

[c] Assays 1-3 1% II, Assays 4-6 1% III

[d] Assays 1-3 1% S-II, Assays 4-6 1% III plus TE

TABLE 5-20

MEANS OF $PO_4^{\equiv}$-P ATTAINED DURING STEADY-STATE OPERATION OF POND ASSAYS

| Pond No. / Assay No. and Residence Time | Means and Coefficients of Variation of $PO_4^{\equiv}$-P Concentrations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1[a] | | 5[a] | | 2[b] | | 6[b] | | 3[c] | | 7[c] | | 4[d] | | 8[d] | |
| | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) | Conc. µg/ℓ | Coef. Var. (%) |
| 1 (8 days) | 2.7 | 37.5 | 2.3 | 34.9 | 4.1 | 33.0 | 4.1 | 30.3 | 13.3 | 23.4 | 14.6 | 26.8 | 20.0 | 11.5 | 17.4 | 31.6 |
| 2 (5 days) | 3.3 | 32.0 | 3.3 | 36.3 | 8.5 | 29.5 | 6.8 | 17.1 | 23.7 | 37.8 | 19.3 | 54.2 | 24.3 | 42.8 | 15.8 | 13.5 |
| 3 (3 days) | 3.6 | 24.7 | 3.8 | 65.5 | 6.4 | 17.8 | 5.8 | 35.4 | 25.6 | 16.9 | 21.4 | 47.0 | 23.6 | 48.2 | 20.2 | 32.8 |
| 4 (8 days) | 4.0 | 46.7 | 3.0 | 23.6 | 3.3 | 17.4 | 3.3 | 17.4 | 3.0 | 33.3 | 3.3 | 17.4 | 3.0 | 33.3 | 2.8 | 39.3 |
| 5 (5 days) | 3.7 | 56.2 | 3.0 | 46.9 | 2.3 | 44.3 | 2.7 | 61.2 | 3.5 | 56.3 | 2.5 | 33.6 | 2.3 | 42.0 | 2.0 | 55.0 |
| 6 (3 days) | 3.5 | 49.4 | 2.8 | 34.9 | 2.3 | 22.2 | 2.8 | 54.5 | 2.7 | 21.7 | 2.0 | 0 | 2.8 | 34.9 | 4.3 | 95.0 |

[a] Lake Tahoe Water

[b] Assays 1-3 0.1% II, Assays 4-6 2% III

[c] Assays 1-3 1% II, Assays 4-6 1% III

[d] Assays 1-3 1% S-II, Assays 4-6 1% III plus TE

## Flask Assays of Pond Effluent

To a very significant degree the experimental ponds used in the study herein reported are analagous to marinas or lagoons in which Lake Tahoe water is detained at temperatures more favorable to algal growth than that of the lake, and is given added nutrients as a result of human activity in the water or on the adjacent land. In such confined waters an assay measures only the growth potential remaining at any given time in the eutrophication cycle. Thus both the growth potential and the existing biomass would have to be measured in order to evaluate the productivity of any given body of water. To explore the residual growth stimulating ability of water after its original nutrients have been reduced by algal growth, flask assays were made during steady state operation of the experimental ponds. Samples for assay were collected from each of the eight ponds during six separate assays of Lake Tahoe water, and three assays each of secondary and tertiary waste water effluent.

Results of these flask assays of 48 pond samples and six Lake Tahoe water samples are summarized in Table 3-21* in which are reported values of growth rates, cell concentration, coefficient of variation for $\hat{\mu}_b$ and $\hat{X}_s$, and the correlation coefficient for $\hat{\mu}_{b\ell}$. Values presented in the table for concentration of sample represent the influent waste concentration established for the pond assay and do not reflect the condition of the various samples drawn from the pond for flask assay.

All of the flask assays from the ponds yielded lower growth response than did flask assays of secondary and tertiary effluent at concentrations equivalent to that fed into the ponds for pond assay purposes. Basically the same growth response pattern was observed when measured by any of the three parameters, $\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_s$. The following discussion therefore applies to all of these parameters.

Examination of Table 3-21 shows that little change in growth response occurred in the pond effluent samples in comparison with that displayed by Lake Tahoe water reference ponds undergoing pond assay. This indicates that little growth effect is to be expected by confining Lake Tahoe water in the absence of added nutrients. Such a circumstance, however, is of little practical consequence because when any detention of Lake Tahoe water does occur, as in marinas or keys, it is impossible to prevent the entry or accumulations of nutrients which result from the human activity which the impoundments or developments were designed to attract.

Flask assays made from ponds operating on secondary and simulated secondary effluents detained as long as eight days showed that there still remained enough nutrients to support a larger biomass than normally measured in Lake Tahoe water. This means, of course, that the growth of organisms during pond bioassays did not strip out enough of the added nutrients to restore Lake Tahoe water to its original degree of purity. Interpreted in terms of lake conditions this would mean that even harvesting of algae from an enriched confined water by chemical precipitation, for example, would not prevent a residue of the nutrient which produced the growth from moving out into the lake.

Flask assays of samples from the pond in assays 4 and 5 and receiving low concentrations of tertiary effluent produced little growth for the simple reason that the tertiary effluent had previously been subjected to both phosphate removal and a growth of organisms under phosphate limited conditions. Thus no residual ability of the pond effluent to support algal growth was identified. This apparent result, however, is misleading because in the phosphorus poor water nitrogen was not utilized and so remained in the flask. Again in terms of a nitrogen sensitive lake, the flask assay represented a situation in which a critical nutrient could be discharged to Lake Tahoe undetected by an assay based on growth stimulating potential.

From Pond Assay 6 the flask assay showed a residual nutrient concentration sufficient to support growth beyond the level found in Lake Tahoe water. The reason for this difference between results on Assay 6, and Assays 4 and 5 lies in the factor of temperature. Pond Assay 6 was conducted at the lowest temperature of all assays hence growth in the ponds was inhibited. At the optimum temperature used in

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*See also Appendix D; Table D-2.

## TABLE 3-21

## MAXIMUM GROWTH RATES, $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$, AND MAXIMUM CELL CONCENTRATION, $\hat{X}_s$, ATTAINED AT THE END OF FIVE DAYS IN FLASK CULTURE OF POND SAMPLES COLLECTED DURING STEADY STATE OPERATION

| Sampling Date, Pond and Assay No. | Source and Conc. of Sample (%) | Mean Max. Rate ($\hat{\mu}_b$, day$^{-1}$) | Coef. Var. (%) | Mean Max. Rate ($\hat{\mu}_{b\ell}$, day$^{-1}$) | Corr. Coef. | Cell Conc. $\hat{X}_s$ (cells/mm$^3$) | Coef. Var. (%) |
|---|---|---|---|---|---|---|---|
| 8- 6-69 | | | | | | | |
| Assay 1 | | | | | | | |
| Pond 1 | LTW[a] | 0.147 | 27.0 | 0.064 | 0.521 | 115.1 | 30.5 |
| 2 | 0.1% II[b] | 0.153 | 35.2 | 0.074 | 0.625 | 125.4 | 21.5 |
| 3 | 1.0% II[c] | 0.243 | 9.4 | 0.160 | 0.939 | 174.1 | 13.1 |
| 4 | 1.0% S-II[d] | 0.508 | 11.8 | 0.294 | 0.912 | 285.3 | 10.1 |
| 5 | LTW | 0.140 | 25.3 | 0.084 | 0.757 | 116.1 | 16.8 |
| 6 | 0.1% II | 0.105 | 12.1 | - 0.018 | - 0.236 | 79.2 | 6.9 |
| 7 | 1.0% II | 0.423 | 7.6 | 0.255 | 0.928 | 248.7 | 4.9 |
| 8 | 1.0% S-II | 0.459 | 8.1 | 0.244 | 0.874 | 246.4 | 13.7 |
| LTW | Header[e] | 0.142 | 32.4 | 0.017 | 0.201 | 92.5 | 7.8 |
| 8-20-69 | | | | | | | |
| Assay 2 | | | | | | | |
| Pond 1 | LTW | 0.068 | 44.3 | 0.027 | 0.453 | 99.1 | 5.3 |
| 2 | 0.1% II | 0.043 | 79.5 | - 0.019 | - 0.348 | 96.2 | 2.0 |
| 3 | 1.0% II | 0.254 | 7.6 | 0.156 | 0.931 | 142.4 | 6.2 |
| 4 | 1.0% S-II | 0.364 | 18.6 | 0.218 | 0.921 | 189.6 | 5.5 |
| 5 | LTW | 0.092 | 26.9 | 0.064 | 0.931 | 96.2 | 4.4 |
| 6 | 0.1% II | 0.064 | 31.8 | 0.043 | 0.834 | 93.[illegible] | 4.2 |
| 7 | 1.0% II | 0.081 | 66.8 | 0.027 | 0.384 | 104.7 | 8.4 |
| 8 | 1.0% S-II | 0.127 | 47.3 | 0.082 | 0.718 | 115.8 | 23.8 |
| LTW | Header | 0.171 | 54.5 | 0.107 | 0.765 | 117.7 | 26.5 |
| 9- 2-69 | | | | | | | |
| Assay 3 | | | | | | | |
| Pond 1 | LTW | 0.416 | 6.0 | 0.317 | 0.958 | 179.0 | 20.4 |
| 2 | 0.1% II | 0.408 | 9.5 | 0.299 | 0.967 | 180.1 | 11.8 |
| 3 | 1.0% II | 0.576 | 11.2 | 0.354 | 0.906 | 320.1 | 14.6 |
| 4 | 1.0% S-II | 0.422 | 22.7 | 0.319 | 0.959 | 220.1 | 10.6 |
| 5 | LTW | 0.436 | 15.2 | 0.276 | 0.911 | 167.3 | 22.5 |
| 6 | 0.1% II | 0.299 | 18.6 | 0.198 | 0.948 | 117.1 | 4.1 |
| 7 | 1.0% II | 0.416 | 57.6 | 0.237 | 0.554 | 392.8 | 53.3 |
| 8 | 1.0% S-II | 0.512 | 10.1 | 0.325 | 0.937 | 467.6 | 12.9 |
| LTW | Header | 0.509 | 9.2 | 0.368 | 0.932 | 221.6 | 7.6 |
| 10- 1-69 | | | | | | | |
| Assay 4 | | | | | | | |
| Pond 1 | LTW | 0.206 | 29.1 | 0.050 | 0.312 | 90.9 | 26.7 |
| 2 | 2% III[f] | 0.359 | 20.1 | 0.179 | 0.846 | 119.1 | 11.3 |
| 3 | 1% III[g] | 0.260 | 24.6 | 0.118 | 0.790 | 96.2 | 11.4 |
| 4 | 1% III + TE[h] | 0.163 | 25.6 | 0.133 | 0.883 | 100.5 | 20.5 |
| 5 | LTW | 0.416 | 24.4 | 0.251 | 0.837 | 186.4 | 18.0 |
| 6 | 2% III | 0.355 | 20.1 | 0.153 | 0.766 | 104.5 | 13.1 |
| 7 | 1% III | 0.215 | 58.6 | 0.120 | 0.740 | 93.3 | 17.0 |
| 8 | 1% III + TE | 0.432 | 55.3 | 0.274 | 0.813 | 182.2 | 44.1 |
| LTW | Header | 0.462 | 18.0 | 0.265 | 0.792 | 146.9 | 25.4 |
| 10-14-69 | | | | | | | |
| Assay 5 | | | | | | | |
| Pond 1 | LTW | 0.545 | 5.8 | 0.347 | 0.944 | 210.6 | 7.7 |
| 2 | 2% III | 0.439 | 13.6 | 0.342 | 0.977 | 192.7 | 8.7 |
| 3 | 1% III | 0.569 | 5.8 | 0.365 | 0.946 | 207.5 | 5.8 |
| 4 | 1% III + TE | 0.550 | 10.3 | 0.384 | 0.961 | 204.4 | 10.7 |
| 5 | LTW | 0.447 | 22.7 | 0.311 | 0.937 | 207.7 | 19.7 |
| 6 | 2% III | 0.369 | 13.4 | 0.256 | 0.952 | 152.6 | 10.5 |
| 7 | 1% III | 0.451 | 32.3 | 0.301 | 0.916 | 232.9 | 21.7 |
| 8 | 1% III + TE | 0.432 | 20.6 | 0.312 | 0.962 | 205.4 | 5.9 |
| LTW | Header | 0.379 | 19.4 | 0.245 | 0.932 | 312.0 | 10.9 |
| 10-27-69 | | | | | | | |
| Assay 6 | | | | | | | |
| Pond 1 | LTW | 0.225 | 15.3 | 0.139 | 0.923 | 252.5 | 5.0 |
| 2 | 2% III | 0.191 | 38.9 | 0.118 | 0.854 | 222.6 | 10.7 |
| 3 | 1% III | 0.599 | 5.4 | 0.408 | 0.961 | 693.8 | 8.8 |
| 4 | 1% III + TE | 0.119 | 66.9 | 0.077 | 0.806 | 170.2 | 16.9 |
| 5 | LTW | 0.160 | 57.0 | 0.085 | 0.712 | 215.4 | 6.9 |
| 6 | 2% III | 0.623 | 13.5 | 0.357 | 0.909 | 643.0 | 15.1 |
| 7 | 1% III | 0.204 | 18.2 | 0.137 | 0.938 | 218.0 | 5.5 |
| 8 | 1% III + TE | 0.231 | 16.1 | 0.157 | 0.949 | 174.6 | 4.2 |
| LTW | Header | 0.125 | 21.2 | 0.098 | 0.842 | 176.2 | 7.8 |

[a] LTW – Pond containing only Lake Tahoe water.

[b] 0.1% II – Pond containing 0.1% secondary sewage effluent from STPUD Water Reclamation Plant and LTW.

[c] 1.0% II – 1% secondary sewage effluent in LTW.

[d] 1.0% S-II – 1% simulated secondary sewage effluent (refer to Table A-1, Appendix A).

[e] Header – Water sample collected from pond influent LTW supply header.

[f] 2% III – Pond containing 2% tertiary sewage effluent from STPUD Water Reclamation Plant and LTW.

[g] 1% III – 1% tertiary sewage effluent in LTW.

[h] 1% III + TE – 1% tertiary sewage effluent with additions of iron and trace elements (refer to Table A-1, Appendix A).

flask assays, however, algae were able to utilize nutrients which their precedecessors in the ponds could not. In terms of lake conditions this could mean that nutrients reaching embayed waters during the cold months could accumulate and then support an algal bloom in the spring. Such a bloom would, of course, disappear with the stripping of nutrients; but by that time the nutrients are in the cycle of growth, decay, and recycle; and eutrophication is advanced thereby.

Flask assays of tertiary effluent conducted in the Indian Creek Study [2] showed that in its undiluted state it was toxic to algae, only when diluted or stripped of its toxic factors by natural events in an impoundment did it support algal growth.

# CHAPTER IV

# RESULTS OF ASSAYS OF CREEK WATERS

## INTRODUCTION

During the 1969 period herein reported the monitoring program initiated in previous years [1,3] was continued on three creeks, each of which represent surface runoff from land areas in different stages of development. As described in Chapter II, Ward, Incline, and Upper Truckee-Trout creeks were taken as representative of relatively undeveloped, newly developed, and well-established urbanized land areas, respectively. Samples taken at approximately monthly intervals were analyzed chemically and assayed for algal growth stimulating ability by the flask assay method. Results of these examinations are summarized in Tables E-1 (Appendix E) and C-3 (Appendix C).

## CHEMICAL QUALITY OF CREEK WATERS

### Inorganic Nitrogen Series

Data from Table E-1 for soluble $NH_3$-N, $(NO_2 + NO_3)$-N, and Total Inorganic-N are presented in Figure 4-1 to show the relationship of the various forms of nitrogen and their variation with time for the three creeks monitored. The figure shows that on February 4, 1969 the concentration of ammonia in Incline Creek reached a high value at a time when this form of nitrogen was decreasing in both Ward and Upper Truckee-Trout creeks. All three, however, showed an abrupt increase in $NH_3$-N in April, although by comparison Incline Creek had by far the highest concentration. Another, although lesser, rise in ammonia appeared in Incline Creek in September at a time when the other creeks showed a slowly increasing $NH_3$-N content but exhibited no explosive change.

The probable cause of the greatest observed variation in ammonia content is directly related to human activity. Lesser effects may be traced to natural variation. Specifically, Incline Creek flows through a golf course upstream from the sampling point used in the study. No official records of fertilization dates or practice are immediately available but the sharp increases in $NH_3$-N in February and April coincide with the time fertilizer application might be expected. Moreover, animal manures are reported as being used on the golf course, surface runoff could therefore be expected to bring in soluble nitrogen.

The rise in $NH_3$-N concentration in all creeks in April reflects a snowmelt condition. Interestingly enough the three creeks responded in a manner which is apparently a function of the degree of development of the drainage area, although there are no data which might evaluate the proportionality. However, if the Ward Creek data is assumed to reflect what might be expected under natural conditions, the $NH_3$-N concentration in April was about doubled by human activity on the Upper Truckee-Trout drainage area, and increased by a factor of eight by activity in the Incline Creek basin. Although these relationships are speculative, the evidence is that the three creeks do represent the surface runoff conditions they were selected to reflect.

There is no obvious way to identify the cause of the rise in $NH_3$-N concentration in Incline Creek in September without more information on the activities which were at a high level at the time. The peak occurred before the moderate (1.7 in.) rainfall in October, hence storm runoff was not involved. It is well known, however, that the Incline area was undergoing intensive development and there is little doubt that the September incident reflects human activity.

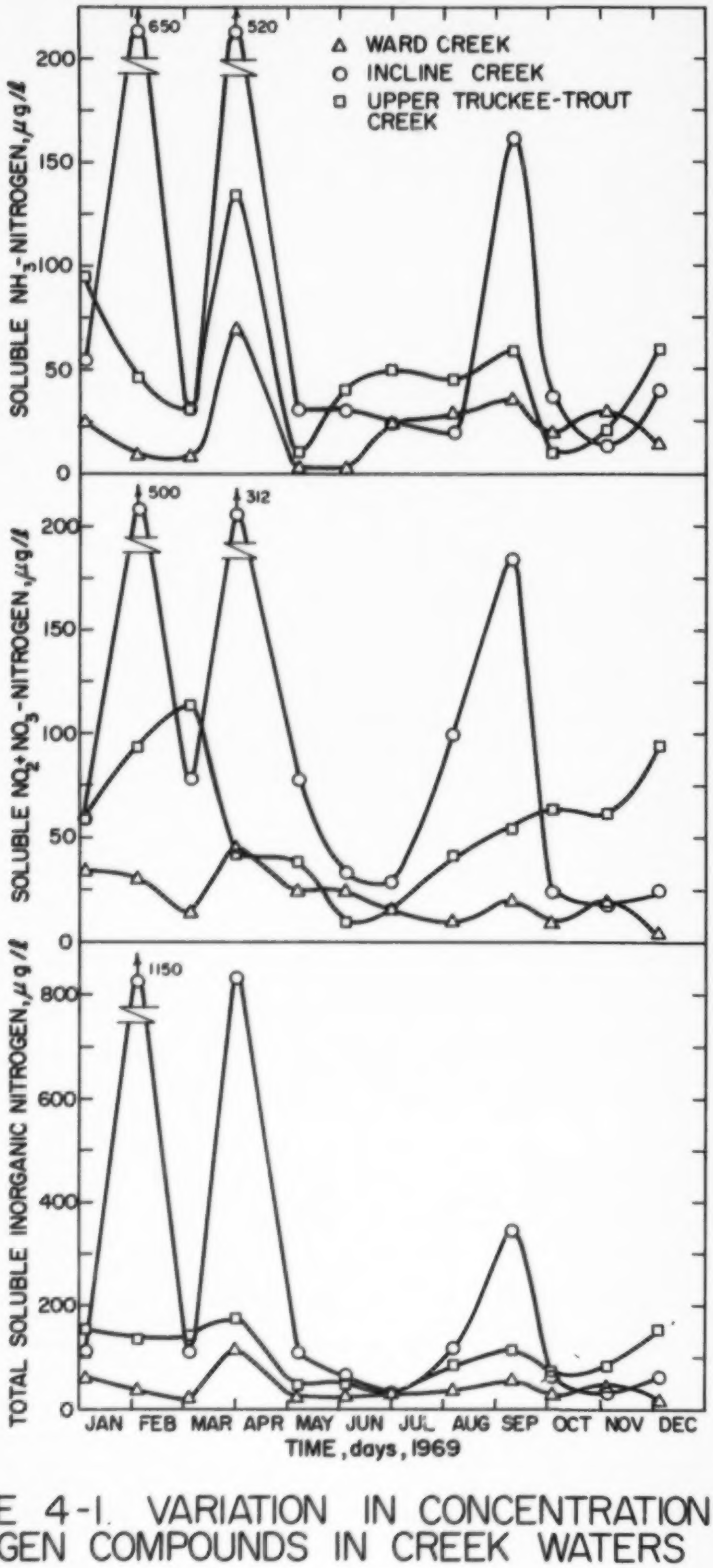

FIGURE 4-1. VARIATION IN CONCENTRATION OF NITROGEN COMPOUNDS IN CREEK WATERS

The plot of values of $(NO_2 + NO_3)$-N concentration shows for Incline Creek the same pattern observed for $NH_3$-N. Ward Creek in April showed a small response associated with the hydrology of the season. The less orderly behavior of Upper Truckee-Trout Creek indicates that its content of more stable forms of nitrogen was not dependent upon the same activity that produced its variation in $NH_3$-N, as seems to be the case for Incline and Ward creeks. The exact activity in the Upper Truckee-Trout basin is unknown but the drainage area is occupied by people and human activity is unpredictable. In this case some discharge of $(NO_2 + NO_3)$-N occurred, which was at a peak in early March and increased again during the June to December period.

Curves for Total Inorganic-N, being the summation of $NH_3$-N and $(NO_2 + NO_3)$-N, show little that has not been discussed previously. Again the intensity of human activity in creek basins is reflected in the position of the individual graphs and seasonal events are identified as to date of occurrence.

## Organic and Total Nitrogen

Figure 4-2 shows that the nitrogen component of Incline Creek in February and April contained soluble organic nitrogen as well as ammonia and $(NO_2 + NO_3)$-N. In late summer, however, two new facts are evident: 1) the maximum concentration of organic nitrogen in Incline Creek occurred on October first rather than in early September, although some organic nitrogen was evidently associated with the early September peak in other forms of nitrogen; and 2) some very large input of organic nitrogen occurred in Upper Truckee-Trout Creek in time for the September sampling. The offset in organic nitrogen curves for Incline and Truckee-Trout creeks, together with the limited response of Ward Creek in September and October, precludes the possibility that a single seasonal phenomenon accounted for the observed concentrations of organic nitrogen reported in Figure 4-2. Obviously human activity on the drainage area is involved. What it might have been must remain speculative.

Because it represents a summation of organic and inorganic nitrogen, the graph of total nitrogen in Figure 4-2 reveals no phenomenon not previously given consideration.

## Ortho and Total Phosphorus

The $PO_4$-P and Total-P values are illustrated in Figure 4-3. As in the nitrogen series two very sharp peaks are apparent for Incline in the February and April samples, however, there was a decrease in September over the previous month rather than an increase as occurred in the nitrogen series. Upper Truckee-Trout and Ward values converged in March and remained almost the same through the August sample. A slight divergence occurred in the plots from September through December.

Values of total phosphorus concentration in Upper Truckee-Trout Creek varied in a pattern similar to that observed for organic nitrogen, i.e., a sudden high rise in early September. Inasmuch as this was obviously not due to $PO_4$-P, it is a further indication that some organic material in unusual amounts was present in Upper Truckee-Trout Creek in September.

## Other Water Quality Factors

Values of such water quality parameters as calcium, conductivity, iron, chlorides, pH, and alkalinity are plotted in Figure 4-4. The various curves indicate that in general all three creeks followed similar seasonal patterns. Chlorides in Incline Creek showed two fairly sharp peaks in February and April paralleling what occurred in the nitrogen and phosphorus series. Although the concentrations were

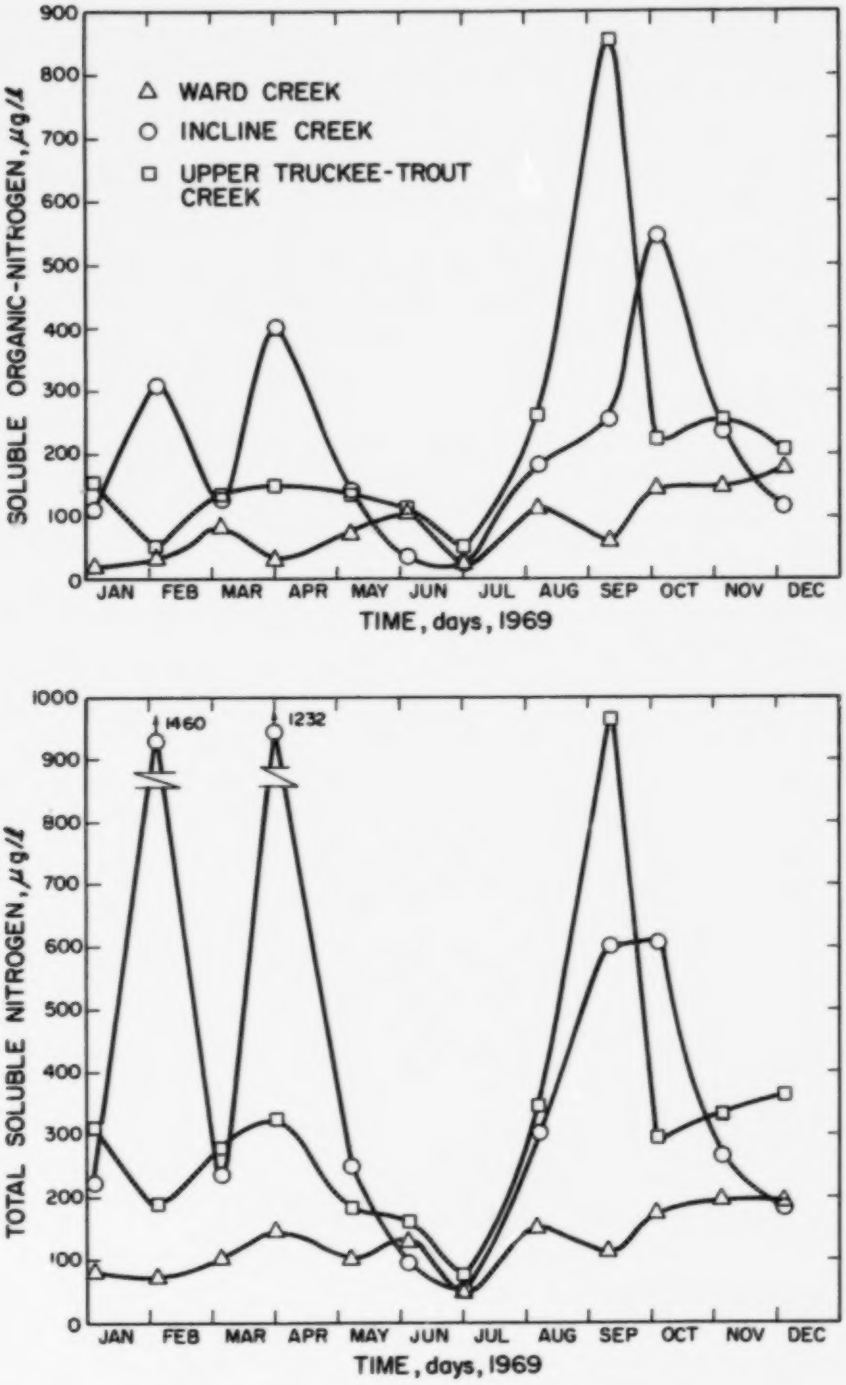

FIGURE 4-2 VARIATION IN ORGANIC AND TOTAL NITROGEN IN CREEK WATERS

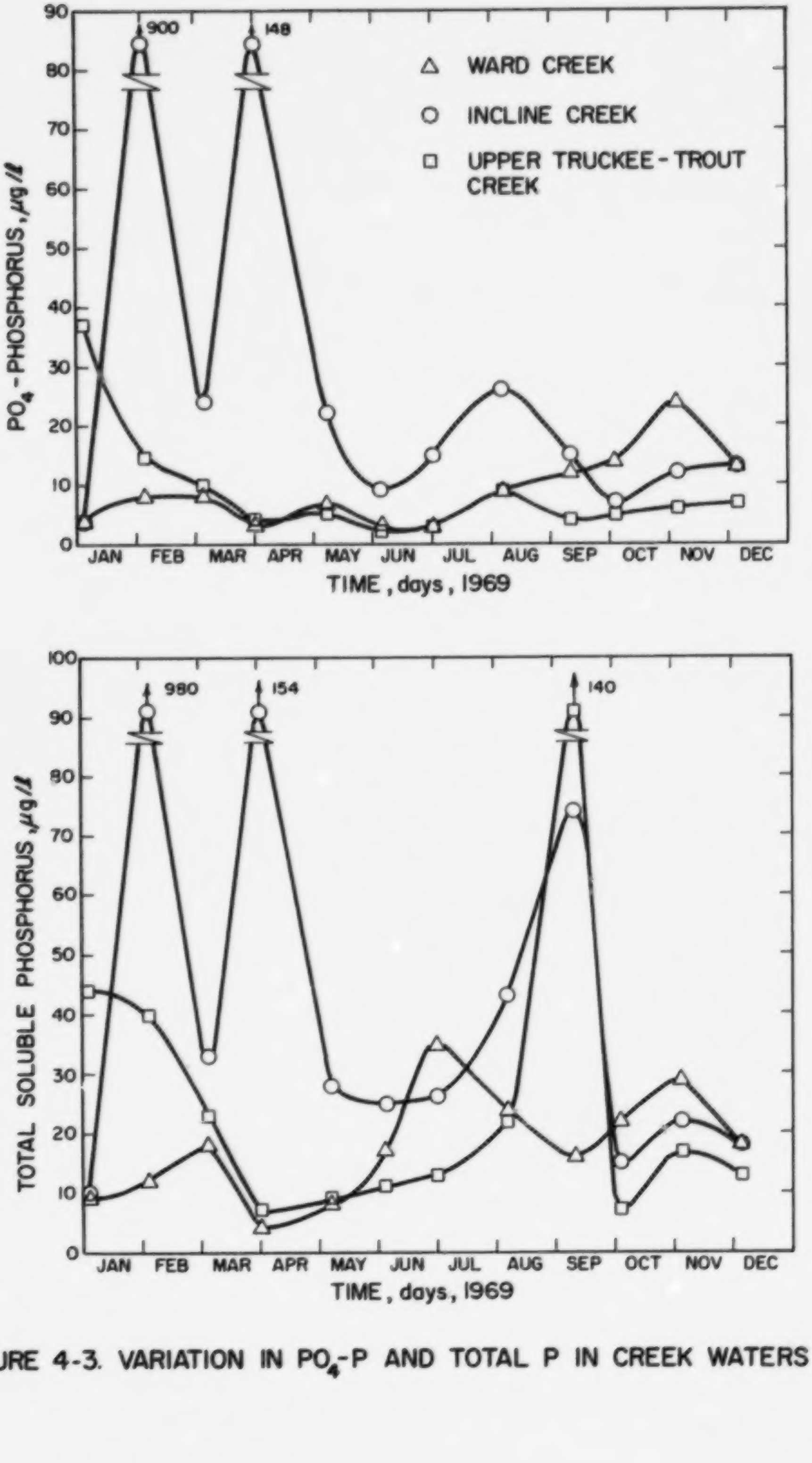

FIGURE 4-3. VARIATION IN $PO_4$-P AND TOTAL P IN CREEK WATERS

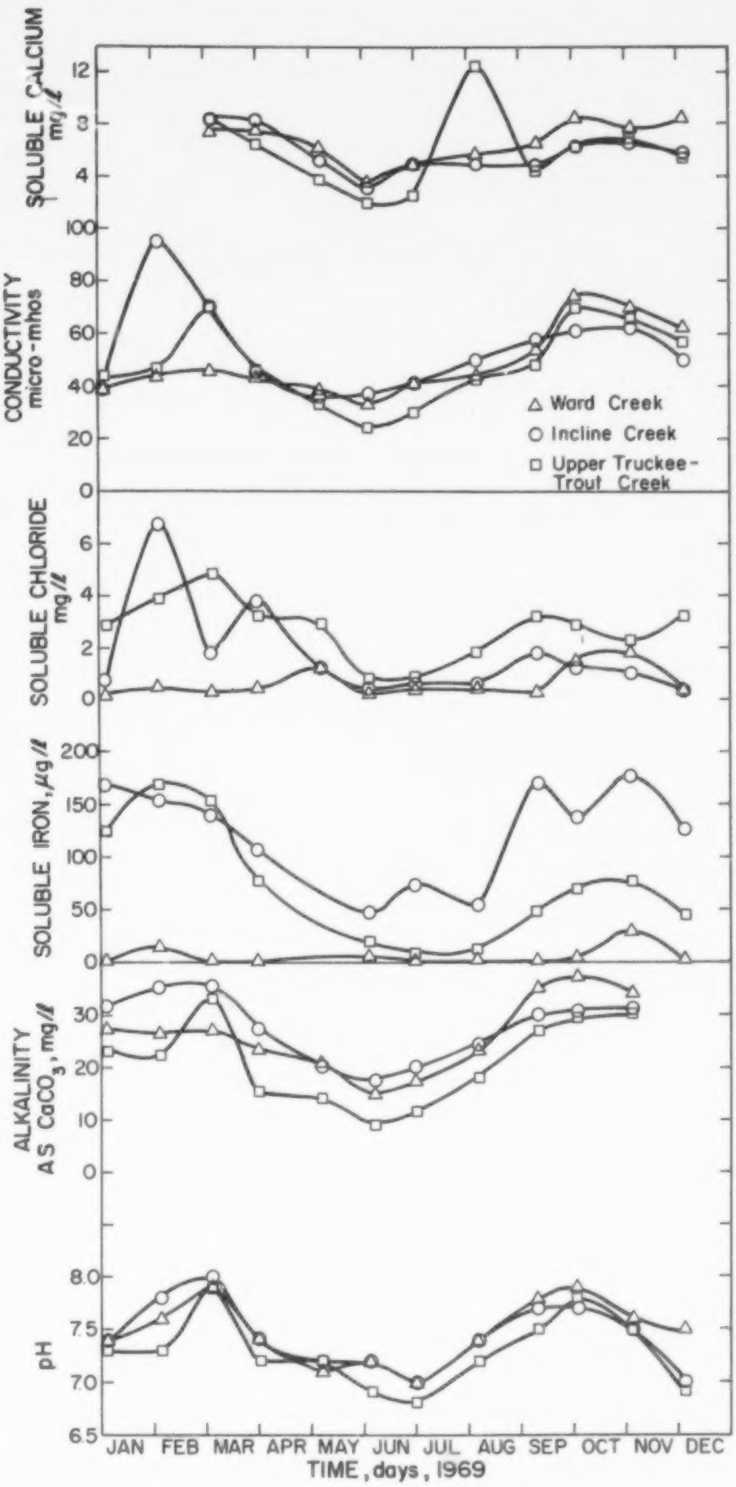

FIGURE 4-4. VARIATION IN CONCENTRATION OF SELECTED WATER QUALITY FACTORS IN CREEK WATERS

not high (4 to 6 mg/$\ell$) human activity is indicated when Incline and Ward creeks are compared. On this same rationale, human activity on the Upper Truckee-Trout area is evident.

For most samples iron in Ward Creek was essentially below the detection level of analytical methods. In both other creeks the iron concentration followed the seasonal pattern of other quality factors - highest in spring and fall; lowest in early and mid-summer.

## GROWTH RESPONSE IN CREEK WATERS

The results of flask assays of creek waters are summarized in Table C-3 (Appendix C). Following the procedure described in Chapter III for shore and mid-lake water samples, growth rates, $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$, and cell concentration, $\hat{X}_5$, were computed for all creeks. The results are summarized in Tables 4-1, 4-2, and 4-3, along with coefficients of variation and correlation coefficients.

As noted in the tables, creek waters assays were made of both undiluted (100% concentration) creek waters and creek waters with an equal amount of Lake Tahoe water (50% concentration) during the period January through June 1969. The objective was to determine both the relative growth stimulating properties of the three creeks and the effect of each in the eutrophication of Lake Tahoe. The data showed, however, that there was not sufficient difference between creek at the 50% concentration and lake water to permit any comparison of their effect on the lake water. Therefore, it was concluded that the most important question is the quantity of nutrients brought into Lake Tahoe by surface runoff, and the effect of land development and human activity on the algal growth stimulating properties of creek water. Consequently, after July 1, 1969 only 100% concentrations of creek waters were assayed.

An examination of Tables 4-1 and 4-3 indicate that the variation within the five replicates was less for the maximum cell concentration, $\hat{X}_5$, than for the maximum growth rate, $\hat{\mu}_b$, for practically all creek assays. Unfortunately, it is impossible directly to compare the precision of the values of $\hat{\mu}_{b\ell}$ with $\hat{\mu}_b$ and $\hat{X}_5$. When the correlation coefficients of $\hat{\mu}_{b\ell}$ for the regression analyses is $\geq 0.749$, the level of significance is at least 99.9%. It is noteworthy that although three of the correlation coefficients of the 50% concentrations were less than 0.749 (or 99.9% level of significance) all of the 100% concentrations were above this value. However, less precision at lower growth rates is to be expected, because small differences at low cell concentrations introduce much greater variability.

A summary of the range of algal growth responses in creek and Lake Tahoe waters is tabulated in Table 4-4. An examination of the table indicates that Ward Creek and Lake Tahoe near shore and mid-lake water samples are not greatly different in any of the three growth response parameters ($\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $X_5$). This is especially noticeable in the cell concentration parameter, $\hat{X}_5$. In contrast, both Incline and Upper Truckee-Trout creeks show appreciably higher values in all three parameters, with Incline Creek being significantly higher than Upper Truckee-Trout Creek. This finding is consistent with those based on nitrogen and phosphorus analyses.

TABLE 4-1

MAXIMUM GROWTH RATES, $\hat{\mu}_g$, ATTAINED DURING FIVE DAYS IN FLASK CULTURE OF CREEK WATERS

| Sampling Date | Conc. of Sample (%) | Source of Sample | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ward Creek | | Incline Creek | | Truckee-Trout Creek | |
| | | Maximum Rate (day$^{-1}$) | Coef. Var. (%) | Maximum Rate (day$^{-1}$) | Coef. Var. (%) | Maximum Rate (day$^{-1}$) | Coef. Var. (%) |
| 1/ 3/69 | 50.0<br>100.0 | 0.1656<br>0.3949 | 37.5<br>28.7 | 0.1461<br>0.5277 | 29.8<br>31.4 | 0.4987<br>0.6533 | 30.1<br>12.2 |
| 2/ 4/69 | 50.0<br>100.0 | 0.7325<br>0.6487 | 21.9<br>14.1 | 1.0390<br>1.1677 | 10.7<br>14.7 | 0.5955<br>0.7685 | 11.2<br>10.0 |
| 3/ 4/69 | 50.0<br>100.0 | 0.5257<br>0.7014 | 23.7<br>4.5 | 0.4752<br>0.6544 | 21.2<br>28.5 | 0.4680<br>0.5484 | 16.8<br>20.6 |
| 4/ 1/69 | 50.0<br>100.0 | 0.4163<br>0.6055 | 23.7<br>6.3 | 0.8029<br>0.8799 | 14.4<br>8.8 | 0.5980<br>0.4321 | 27.8<br>30.8 |
| 5/ 6/69 | 50.0<br>100.0 | 0.3449<br>0.4695 | 55.6<br>12.4 | 0.6597<br>0.6770 | 9.1<br>10.6 | 0.4668<br>0.4333 | 5.8<br>27.8 |
| 6/ 4/69 | 50.0<br>100.0 | 0.3584<br>0.5133 | 25.9<br>45.0 | 0.4370<br>0.6394 | 21.6<br>28.1 | 0.5391<br>0.5689 | 34.0<br>15.2 |
| 7/ 1/69 | 100.0 | 0.4513 | 8.8 | 0.5505 | 2.7 | 0.4878 | 9.2 |
| 7/ 1/69 | 100.0 | 0.2166 | 22.2 | 0.4203 | 11.0 | 0.2356 | 19.6 |
| 8/ 5/69 | 100.0 | 0.5672 | 26.7 | 0.5853 | 45.0 | 0.2193 | 26.6 |
| 8/ 8/69[a]<br>8/ 8/69[b]<br>8/ 8/69[c] | 100.0<br>100.0<br>100.0 | -<br>-<br>- | -<br>-<br>- | 0.3791<br>0.7051<br>0.5187 | 13.0<br>3.0<br>11.0 | -<br><br>- | -<br><br>- |
| 9/10/69 | 100.0 | 0.6350 | 14.8 | 0.6945 | 26.4 | 0.6010 | 25.6 |
| 10/ 2/69 | 100.0 | 0.7364 | 0.9 | 0.5981 | 5.8 | 0.9098 | 6.8 |
| 11/ 6/69 | 100.0 | 0.4676 | 2.6 | 0.4734 | 12.9 | 0.5401 | 9.7 |
| 12/14/69 | 100.0 | 0.2802 | 20.3 | - | - | 0.3395 | 7.9 |

TABLE 4-2

MAXIMUM GROWTH RATE, $\hat{\mu}_g$, AND COMPUTED CORRELATION COEFFICIENT, IN FLASK CULTURE OF CREEK WATERS

| Sampling Date | Conc. of Sample (%) | Source of Sample | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ward Creek | | Incline Creek | | Truckee-Trout Creek | |
| | | Maximum Rate (day$^{-1}$) | Corr. Coef. | Maximum Rate (day$^{-1}$) | Corr. Coef. | Maximum Rate (day$^{-1}$) | Corr. Coef. |
| 1/ 3/69 | 50.0<br>100.0 | 0.084<br>0.289 | 0.642<br>0.928 | 0.047<br>0.250 | 0.458<br>0.786 | 0.332<br>0.451 | 0.928<br>0.938 |
| 2/ 4/69 | 50.0<br>100.0 | 0.327<br>0.463 | 0.790<br>0.960 | 0.922<br>0.962 | 0.993<br>0.989 | 0.598<br>0.683 | 0.946<br>0.986 |
| 3/ 4/69 | 50.0<br>100.0 | 0.357<br>0.335 | 0.918<br>0.827 | 0.340<br>0.368 | 0.959<br>0.877 | 0.320<br>0.343 | 0.953<br>0.912 |
| 4/ 1/69 | 50.0<br>100.0 | 0.314<br>0.377 | 0.967<br>0.941 | 0.696<br>0.769 | 0.992<br>0.993 | 0.311<br>0.264 | 0.852<br>0.906 |
| 5/ 6/69 | 50.0<br>100.0 | 0.184<br>0.254 | 0.780<br>0.872 | 0.411<br>0.423 | 0.918<br>0.929 | 0.184<br>0.277 | 0.715<br>0.908 |
| 6/ 4/69 | 50.0<br>100.0 | 0.178<br>0.246 | 0.766<br>0.760 | 0.287<br>0.364 | 0.924<br>0.885 | 0.174<br>0.447 | 0.572<br>0.976 |
| 7/ 1/69 | 100.0 | 0.255 | 0.909 | 0.331 | 0.951 | 0.299 | 0.951 |
| 7/ 1/69 | 100.0 | 0.126 | 0.892 | 0.267 | 0.942 | 0.167 | 0.941 |
| 8/ 5/69 | 100.0 | 0.292 | 0.846 | 0.327 | 0.901 | 0.107 | 0.775 |
| 8/ 8/69[a]<br>8/ 8/69[b]<br>8/ 8/69[c] | 100.0<br>100.0<br>100.0 | -<br>-<br>- | -<br>-<br>- | 0.276<br>0.445<br>0.307 | -0.966<br>0.943<br>0.916 | -<br>-<br>- | -<br>-<br>- |
| 9/10/69 | 100.0 | 0.371 | 0.915 | 0.509 | 0.962 | 0.377 | 0.912 |
| 10/ 2/69 | 100.0 | 0.451 | 0.959 | 0.323 | 0.895 | 0.495 | 0.897 |
| 11/ 6/69 | 100.0 | 0.410 | 0.967 | 0.325 | 0.953 | 0.337 | 0.951 |
| 12/ 4/69 | 100.0 | 0.190 | 0.940 | - | - | 0.162 | 0.823 |

Correlation coefficient required for 99.9% significance level = 0.749

TABLE 4-3

MAXIMUM CELL CONCENTRATIONS, $\hat{X}_g$, ATTAINED AT THE END OF FIVE DAYS IN FLASK CULTURE OF CREEK WATERS

| Sampling Date | Conc. of Sample (%) | Source of Sample | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ward Creek | | Incline Creek | | Truckee-Trout Creek | |
| | | Cell Conc. (cells/mm$^3$) | Coef. Var. (%) | Cell Conc. (cells/mm$^3$) | Coef. Var. (%) | Cell Conc. (cells/mm$^3$) | Coef. Var. (%) |
| 1/ 3/69 | 50.0<br>100.0 | 72.60<br>155.00 | 37.5<br>21.2 | 67.80<br>155.40 | 15.7<br>24.1 | 209.00<br>365.20 | 22.0<br>11.1 |
| 2/ 4/69 | 50.0<br>100.0 | 107.40<br>181.20 | 17.1<br>20.1 | 1429.60<br>1812.80 | 8.3<br>15.5 | 230.00<br>1072.00 | 22.3<br>12.5 |
| 3/ 4/69 | 50.0<br>100.0 | 168.00<br>189.60 | 9.5<br>19.8 | 232.60<br>395.20 | 7.0<br>19.2 | 222.60<br>264.00 | 10.7<br>26.5 |
| 4/ 1/69 | 50.0<br>100.0 | 140.00<br>162.00 | 5.3<br>7.3 | 667.00<br>974.00 | 18.6<br>3.9 | 133.60<br>140.40 | 10.5<br>2.7 |
| 5/ 6/69 | 50.0<br>100.0 | 142.60<br>185.80 | 17.1<br>14.3 | 244.40<br>382.80 | 22.3<br>23.9 | 137.20<br>249.80 | 14.3<br>7.2 |
| 6/ 4/69 | 50.0<br>100.0 | 89.00<br>107.80 | 25.7<br>29.3 | 124.00<br>129.60 | 11.6<br>21.7 | 76.60<br>242.20 | 31.4<br>11.2 |
| 7/ 1/69 | 100.0 | 127.04 | 6.1 | 171.84 | 7.0 | 156.16 | 7.7 |
| 7/ 1/69 | 100.0 | 84.56 | 7.0 | 172.32 | 6.7 | 120.48 | 9.3 |
| 8/ 5/69 | 100.0 | 236.48 | 8.3 | 272.20 | 4.3 | 102.96 | 12.9 |
| 8/ 8/69[a]<br>8/ 8/69[b]<br>8/ 8/69[c] | 100.0<br>100.0<br>100.0 | -<br>-<br>- | -<br>-<br>- | 213.60<br>502.60<br>596.20 | 4.6<br>11.1<br>4.3 | -<br>-<br>- | -<br>-<br>- |
| 9/10/69 | 100.0 | 315.92 | 9.9 | 1092.00 | 9.4 | 524.80 | 9.4 |
| 10/ 2/69 | 100.0 | 282.40 | 1.6 | 177.36 | 6.7 | 411.40 | 6.0 |
| 11/ 6/69 | 100.0 | 273.7 | 20.2 | 263.00 | 11.7 | 220.8 | 6.6 |
| 12/ 4/69 | 100.0 | 154.9 | 11.2 | - | - | 155.00 | 12.7 |

[a] Sample collected above Incline Village in undisturbed area.

[b] Sample collected below construction zone in Incline Village.

[c] Sample collected below golf course (50 yd above Highway 28).

TABLE 4-4

SUMMARY OF THE RANGE OF ALGAL[a] GROWTH RESPONSE IN CREEK WATERS
IN 1969 AS MEASURED BY GROWTH RATES AND CELL CONCENTRATIONS
(mean of 5 replicates)
(100% concentrations)

| Source of Sample | Range of Growth | | |
|---|---|---|---|
| | Rate $\hat{\mu}_b$, days$^{-1}$ | Rate $\hat{\mu}_{b\ell}$, days$^{-1}$ | Range of Cell Concentration $\hat{X}_5$, cells/mm$^3$ |
| Ward Creek | 0.217-0.736 | 0.126-0.463 | 84.6- 315.9 |
| Incline Creek | 0.420-1.168 | 0.250-0.962 | 129.6-1812.8 |
| Upper Truckee-Trout Creek | 0.219-0.910 | 0.107-0.683 | 103.0-1072.0 |
| Lake Tahoe | | | |
| Near Shore[b] | 0.135-0.640 | 0.110-0.360 | 90.0- 263.9 |
| Mid-Lake | 0.055-0.579 | 0.043-0.361 | 54.4- 219.3 |

[a] Culture inoculated with *Selenastrum gracile* to July 1, 1970 and with *Selenastrum capricornutum* thereafter (see Table C-3, Appendix C).

[b] Grab samples from U. S. Coast Guard Pier.

## Seasonal Variation

The seasonal variation in the maximum algal growth rates ($\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_5$) and cell concentrations in 100% sample concentrations of creek waters (Tables 4-1, 4-2, and 4-3) are shown graphically in Figure 4-5. It is noteworthy that all three growth parameters, $\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_5$, compare very well for Incline Creek, however only $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$ compare favorably for Upper Truckee-Trout Creek. There was only moderate correlation between the three growth parameters for Ward Creek. Cell concentration, $\hat{X}_5$, for Upper Truckee-Trout did compare with the other two for the first three months of the year but during the rest of the year there was discontinuity in the correlation.

It is interesting to note that the growth responses of Incline Creek corresponded very well with the increases and decreases in concentrations of $NH_3$-N, ($NO_2$ + $NO_3$)-N, total inorganic nitrogen, total nitrogen, total phosphorus, and chloride. There was also fair correlation during part of the year with organic nitrogen and $PO_4$-P. Organic nitrogen would not be expected to necessarily have good correlation with growth responses, however, it is surprising that $PO_4$-P did not correlate better. The slight rise in the constituent concentration in December for $NH_3$-N ($NO_2$ + $NO_3$)-N, total inorganic nitrogen, total nitrogen, and $PO_4$-P was not apparent in the growth responses. Unfortunately there was little apparent correlation between changes in constituent concentrations and growth responses for Upper Truckee-Trout and no apparent correlation for Ward Creek.

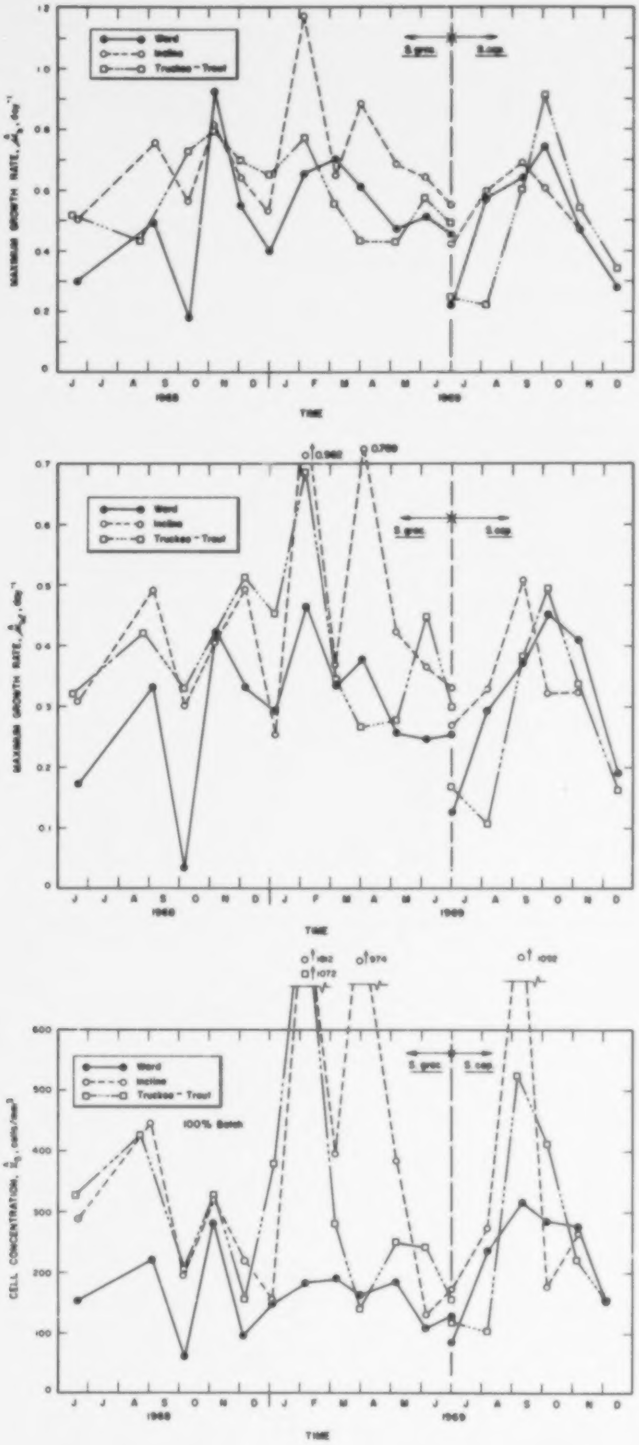

FIGURE 4-5. COMPARISON OF ALGAL GROWTH RESPONSE PARAMETERS IN FLASK ASSAYS OF CREEK WATERS

## Conclusions

The results of flask assays of creek waters support the conclusions that:

1. During the period of study herein reported runoff from relatively undeveloped land, as measured by Ward Creek, was only slightly more capable of producing algal growth than Lake Tahoe water itself.
2. There is a definite increase in nutrients in creek waters as the level of human occupancy and development of land increases, which is evident in both chemical analyses and bioassays.
3. During the period of observation Incline Creek was consistently more capable of supporting algal growth than was Upper-Truckee-Trout Creek, which in turn was more capable than Ward Creek of supporting such growth.
4. There is evidence of discharge of organic matter into Upper Truckee-Trout Creek about September 1969.

## MICROSCOPIC ANALYSES

In April 1970 a microscopic survey of waters and bottom deposits was made on Burton Creek, above the Star Harbor development, and at the mouth of the lagoon which is a part of the development. At the same time a sample of Lake Tahoe water was obtained from the Coast Guard Pier.

The results are summarized in Table 4-5.

From the single survey summarized in Table 4-5 it is evident that the greatest diversity of organisms appeared in the water at the mouth of the Star Harbor lagoon. This sample exhibited a very limited stagnant water flora and fauna. In the lake itself only diatoms were observed. Diatoms predominated in the Burton Creek samples as well but ciliate protozoa were also present.

## TABLE 4-5

## RESULTS OF MICROSCOPIC ANALYSIS OF CREEK AND LAKE WATERS

| Description and Location of Sample | Organisms |
|---|---|
| Lake Tahoe Water from Coast Guard Pier | Chrysophyta (Diatoms)<br>Navicula<br>Synedra ulma<br>Synedra capitata<br>Gomphonema (separate from stalk) |
| Water Sample, Mouth of Star Harbor Lagoon | Chlorophyta<br>Ulothrix<br>Phytomonads<br>Carteria<br>Cyanophyta<br>Anabaena<br>Chrysophyta<br>Gomphonema<br>Ciliate Protozoa (numerous)<br>Cinetochilum<br>Holosticha<br>Miscellaneous Organisms<br>Rotifer |
| Benthic Sample Mouth of Star Harbor Lagoon (top 2 mm of benthos) | Chlorophyta<br>Ulothrix<br>Chrysophyta (Diatoms)<br>Gamphonema<br>Navicula<br>Fragilaria crotenis<br>F. capitator<br>Pinnularia<br>Ciliate Protozoa<br>3 genera (unidentified)<br>Zooflagellate<br>(unidentified) |
| Burton Creek near Highway 28 (benthic sample) | Chrysophyta (Diatoms)<br>Navicula<br>Gomphonema<br>Cymbella<br>Melosira<br>Ciliate Protozoa<br>Cinetochilum<br>Oxytricha |
| Burton Creek at Bridge above Star Harbor Lagoon (benthic sample) | Chrysophyta (Diatoms)<br>Navicula<br>Pinnularia<br>Synedra capitata<br>Rhapalodia<br>Flagellate Protozoa<br>Astasia<br>Cyclidium<br>Testacea<br>Trinema<br>Hyalosphenia |

# CHAPTER V

# EVALUATION OF RESULTS

## INTRODUCTION

During the year of study herein reported, progress continued in accord with the schedule established at the beginning of the project. Both in reliability and extent of data the point was reached where initial interpretations of the results may be made in terms of the eutrophication of surface waters in general, and of Lake Tahoe in particular — the overall objective of the demonstration grant project. Interpretations and evaluations of specific findings have already been presented in Chapters III and IV as individual aspects of the results were introduced. In what follows, a broader and more general evaluation is presented.

To a certain degree any evaluation of scientific findings involves documenting the obvious. Unfortunately, where legal decisions, regulatory action, or public policy decisions are to be made numbers must be applied to establish facts generally well known to scientific specialists. This is particularly true in 1970 when public concern over such qualitative factors as "pollution," "environmental quality," and even "eutrophication" leads to demands for public investment or legal constraints which may or may not be wise, or even feasible. Moreover, a fact which seems obvious to the purist may turn out to be trivial when numerical values are applied to the spectrum of facts to which it belongs. Conversely, where economic interests are involved, an action which is obviously harmless to the interest may be one of major or catastrophic environmental concern when it is evaluated numerically. Nor is it without precedent in such cases for the entrepreneur to take refuge in the fact that controls are lacking for want of documentation of what seems obvious to "experts," or of proof that what is true in general applies in any specific set of circumstances. It is within the framework of such a rationale that the current findings of the project are herein considered.

## POND AND FLASK ASSAYS

From the pond assays and associated chemical analyses and environmental observations it is clear that an increase in algal growth response follows the introduction of any amount of sewage effluent or other source of nutrients in water, and increases with the concentration of such nutrients as long as some single nutrient is not so limited as to represent the controlling factor. In the case of Lake Tahoe water, which is not in itself capable of furnishing an important supply of nitrogen, the growth of algae in dilute secondary effluent was limited by the ability of indigenous organisms (principally diatoms) to make the most of a limited supply of nitrogen. In the case of tertiary effluent, which had been subject to phosphorus removal and limited nitrogen removal, growth in Lake Tahoe water was limited by the phosphorus present in effluent plus the small amount of phosphorus which the lake itself could furnish. Assuming that the lake water is nitrogen sensitive as evidence presented by the authors has previously [1,3] suggested, the amount of phosphorus available for algal growth was still of the order of 2 to 4 μg/ℓ. In the presence of nitrogen in amounts equal to from 40 to 100 times this amount of phosphorus, organisms capable of utilizing only 10 to 15 times as much nitrogen as phosphorus were patently unable to convert the available nitrogen to algal cells. Moreover, flask bioassays of water taken from the ponds after steady state growth of algae had been achieved, with either secondary or tertiary effluent, or added chemical nutrients, showed that the water still had a greater ability than Lake Tahoe water itself to stimulate algal growth.

Because the ponds simulated the shallows of Lake Tahoe, the foregoing findings have important implications in terms of eutrophication of the lake. First they mean that if, as in the case of tertiary effluent, algae were grown in a pond of enriched water in which phosphate was in short supply, removal of the algae before discharge to the lake would neither:

a. eliminate the ability of the effluent to stimulate growth in lake water, although that ability would be reduced, nor

b. proportionally reduce the nitrogen to which the lake is sensitive.

This rationale was further reinforced by a comparison of assays of Lake Tahoe water, having added secondary sewage effluent, with simultaneous assays of lake water containing chemical nutrients in approximately the same concentration as the sewage effluent. The results documented an already well known fact that in the bioconversion of nitrogen and phosphorus in organic matter to available forms, other microstimulants not found in chemical additives are generated. In terms of eutrophication of surface waters this would mean that sewage or animal manures should have a different effect than commercial chemicals in fertilizing waters.

In the case of nitrogen poor water, algal growth and removal would leave a residual ability to stimulate growth, plus an excess of phosphate in a form available to organisms. In a receiving water initially short in phosphorus, further algal growth would be stimulated by any soluble nitrogen, or, by atmospheric nitrogen fixed by blue-green algae.

Although no one envisions introducing sewage effluents directly into Lake Tahoe, and the possibility of indirect inputs is rapidly being minimized, the foregoing findings have implications to Lake Tahoe which should be considered. The experimental ponds represent quite distinctly impoundments or embayments of Lake Tahoe water to which nutrients have been added. Thus they simulate marinas, keys, or other confinements of water. Because, such confinements are for the purpose of attracting and making possible concentrated human activity it must be presumed that nutrients will be added to the confined waters both as a result of the carelessness and untidiness of people and the nature of the equipment and material associated with the activity. Thus the source of nutrients may range all the way from food scraps and detergents to fertilizers applied to lawns; and the manure of pets. Once in the relatively confined water algal growth will occur in the warmer season. The residual capacity of the water to stimulate growth will be flushed out into the lake. Eventually the aquatic growth itself will die and becomes a part of the nutrient budget of the lake. During the season when temperatures are inimical to aquatic growth, nutrients will either accumulate in the confinement or move out into the lake, depending upon the nature of the flushout involved in the design of the confinement. Finally, the diverse plankton species generated in the confinement will become a part of the lake population.

A comparison of bioassays and chemical analyses of water samples taken near the shore and at mid-Lake Tahoe reveal that there is essentially no difference in the two. Therefore the implications obtained from pond assays are generally applicable to lake water.

Flask assays of the same tertiary effluent used in pond assays showed that in an undiluted state it was toxic to the test alga, Selenastrum. Similar toxicity to rainbow trout was observed by the California Department of Fish and Game. Evidence points to ammonia-N as the toxic material. In the pond assays, dilution to one percent and two percent was made with Lake Tahoe water and algal growth was stimulated, subject to limitation by phosphorus. Whether any small residual effect of toxicity was involved could not be determined. However, when impounded at Indian Creek Reservoir under conditions of dilution to 80 percent of its original concentration, natural processes removed and converted the $NH_3$-N to gas and to stable forms. Thereafter rainbow trout thrived in the reservoir and plankton growth gave evidence of a highly productive body of water. Benthic biota showed only a small diversity of species but it is too soon to say whether this was the result of toxicity or of transient conditions as the impoundment matured. Preliminary evidence is that the latter was the case. From the standpoint of eutrophication of surface waters the question of the effectiveness of tertiary treatment in preventing eutrophication of highly oligotrophic waters remains for further data to resolve.

In considering the question of the effect of tertiary treatment on the eutrophication of surface waters it cannot be emphasized too strongly that the STPUD effluent assayed during the past year does not represent the ultimate in tertiary treatment. The reclamation plant is still under operational development and is by no means achieving its eventual capability to remove nitrogen. Continued monitoring of Indian Creek Reservoir and bioassays of the plant effluent will lead to more refined conclusions in the future. Presently blue-green algae in no significant amounts as regards the quality of the water exist on the bottom in the shallow portion of a holding pond, indicating their ability to utilize phosphorus from the benthos to support a limited growth. Analysis of pond assays by materials balance and kinetic techniques lead to the conclusion that the secondary effluents assayed during the period of study were nitrogen limited and tertiary effluents were phosphorus limited. Either one, or its equivalent in nutrients from any source, would constitute a hazard to the quality of Lake Tahoe in terms of increasing its natural rate of eutrophication.

## CREEK ASSAYS

Inasmuch as sewage effluents are not to be discharged to Lake Tahoe, the findings herein reported are more applicable to surface waters in general than to the lake. However, one major objective of the study is to evaluate human occupancy of the Lake Tahoe Basin, and of the natural ecology of the Basin, in terms of eutrophication of Lake Tahoe. To this end collection of data on the nutrient concentration and growth stimulating potential of surface runoff to Lake Tahoe has been in progress for some three years. An evaluation of its probable effect on Lake Tahoe is scheduled for the 1970-1971 period of study. Because the scale of the project did not initially permit monitoring of every surface input to the lake, three creeks were selected as representing typical conditions. Specifically:

1. Incline Creek was selected to represent runoff from a newly developed and developing land area.
2. Upper Truckee-Trout Creek, represented a well established area of land development.
3. Ward Creek, represented a generally undeveloped land area.

Results show that Incline Creek throughout the year was lacking in clarity and carried significantly greater amounts of nutrients than did the other two streams. Peak concentrations of nutrients occurred at times when golf course fertilization might be expected, although historical data necessary to pinpoint the source have yet to be collected. The Upper Truckee-Trout Creek data reflect a less explosive change in quality but a water constantly more enriched than that from an undisturbed area. Evidence indicates that at one time of the year organic matter was dumped into the Truckee-Trout system — a possibility always present when humans are present. Ward Creek, in contrast with the other two, showed a much lesser content of nutrients subject to seasonal variation explainable by natural events.

Bioassays of creek water showed that in terms of growth stimulating potential Ward Creek was quite similar to Lake Tahoe. The other two showed greater stimulation proportional to their nutrient content. The effect of such flows on the eutrophication of Lake Tahoe is, of course, a function of both nutrient concentration and quantity of water. Data on this latter factor are being assembled for analyses during the 1970-1971 period of study. The chemical and biological data observed during the 1969-1970 period, however, constitute unmistakeable evidence that the presence of man in the Lake Tahoe Basin leads to nutrient enrichment of the lake, quite aside from sewage effluents, to a degree yet to be evaluated.

## ENVIRONMENTAL OBSERVATIONS

Environmental factors affecting the quality of Lake Tahoe, and related to human activity, are noted to a limited degree in the body of the report. Shoreline development at the mouth of Burton Creek at north Lake Tahoe was observed to generate a silt input early in 1969. Later in the year wind generated mixing of shallow water at the site, stirred up inorganic sediments not normally observed in the waters of the area. A plankton survey of the area in April 1970 showed a vastly greater species diversity than in Burton Creek above the lagoon. This is further evidence that man's activities in disturbing land and impounding water are reflected in inputs to Lake Tahoe which add to its rate of eutrophication.

## PLANS FOR THE FUTURE

During the 1970-1971 study season the project plan calls for collecting and analyzing the necessary data to make possible an estimate of the nutrients going into Lake Tahoe; a comparison of sewage and other sources of nutrients in a populated area; and an interpretation of the results in terms of eutrophication of surface waters and particularly of Lake Tahoe.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

During the period June 1969 through May 1970 ongoing studies of the eutrophication of surface waters, with special reference to Lake Tahoe, were continued under the terms of Demonstration Grant No. 16010 DSW made to the Lake Tahoe Area Council by the Federal Water Quality Administration. The general objective of the study was to evaluate the relative algal growth potential of various sources of nutrients which may find their way into surface waters. Effluents from various degrees of sewage treatment; runoff from inhabited and uninhabited land areas; seepage from septic tanks and refuse fills; drainage from swamps; and precipitation directly on the water were considered as possible sources of nutrients leading to eutrophication of surface waters. In the specific case of Lake Tahoe, impoundments and shoreline activity were also of concern; and although no proposal to discharge sewage effluents directly to the lake was made, the value of exporting waste water from the basin as a device to control eutrophication was important because export of sewage might not be the only measure needed to protect the lake.

During the period herein reported investigative work was concerned primarily with:

1. Pilot pond bioassays of algal growth response to nutrients added to Lake Tahoe water as small amounts (0.1% to 2.0%) of secondary and tertiary waste water effluents or as inorganic chemicals, together with related chemical analyses.

2. Flask bioassays and chemical analyses to monitor the levels of, and seasonal changes in, quality of:

    a. Lake Tahoe.

    b. Creeks traversing relatively undeveloped, newly developed, and well established urbanized land.

    c. Confined waters already productive of algae.

3. Environmental data pertinent to an interpretation of the findings from the chemical and biological analyses listed above.

4. Comparison of the growth stimulating properties of tertiary effluent in Lake Tahoe water with that of the same effluent impounded in Indian Creek Reservoir.

Pursuant to the objectives of the study, six pond bioassays were made during the July through October 1969 period. Flask bioassays of lake and creek water were made at approximately monthly periods throughout the year, and flask bioassays of pond effluents were made at the close of each pond assay period. Appropriate chemical analyses were made at frequent intervals, and environmental and climatological factors were observed daily.

Based on an analysis of the results of the study with which the body of the report is principally concerned the following conclusions and observations seem justified at this time.

1. From chemical and flask bioassays the quality of near-shore water was shown to be representative of the lake, hence it is concluded that the results of pond assays of near-shore water can be interpreted in terms of other sectors of the lake water under similar conditions of temperature and added nutrients.

2. Suspended solids in the shallow portions of the lake depreciated its aesthetic quality locally when wind direction and velocity was right for pickup of silt discharged to the lake as a result of land development.

3. The phosphorus content of Lake Tahoe varied but little during the period of pond assays (July-October). At all times it was at the lower limit of accurate measurement by present analytical methods, most values being in the 2 to 4 μg/ℓ range.

4. Although the concentration of all forms of nitrogen in Lake Tahoe is quite small a seasonal change in $(NO_2 + NO_3)$-N was readily observable.

5. Under steady state pond assays of secondary sewage effluent in Lake Tahoe water at concentrations of 0.1% and 1.0%, nitrogen was determined to be the growth limiting nutrient. Phosphorus was limiting in assays of 1% and 2% tertiary effluent.

6. Simulated secondary effluent based on the addition of $NH_3$-N, $PO_4$-P, iron, and micronutrients produced a different growth response as did secondary effluent of the same apparent analysis. It is concluded that life processes themselves contribute growth stimulants which the analyses adopted for the study did not reveal.

7. In pond assays of tertiary effluents the growth response was so severely phosphorus limited that neither the materials balance nor the kinetic equation yielded statistically significant correlation coefficients. The apparent reason is that all data fall on the flat region of the cell mass versus residence time curve.

8. The tertiary effluent assayed in the study was secondary sewage treatment plant effluent which had been subjected to phosphate removal, carbon filtration, and nitrogen reduction by ammonia stripping. However, because the tertiary process itself was a new demonstration unit undergoing development, the residual $NH_3$-N in the effluent was in the range of 12 to 17 mg/ℓ, hence more than may be expected of tertiary effluents in the future.

9. Undiluted tertiary effluent was observed to be toxic both to rainbow trout and to the test alga Selenastrum, although capable of stimulating algal growth when diluted to low concentrations with Lake Tahoe water. After impoundment at Indian Creek Reservoir had brought various natural forces into play to reduce its $NH_3$-N content and otherwise condition the effluent, it proved productive of biota although but little diluted by surface runoff.

10. Pond assays of nutrient enriched Lake Tahoe water failed to show the expected reduced growth response in late fall when the water temperature fell below 10°C.

11. A statistical fit of the materials balance equation to data on pond assays of secondary effluents gave statistically significant correlation coefficients at the 95% confidence level in all but 2 of 18 assays.

12. From a kinetic analysis of data from pond assays of the growth stimulating ability of secondary and tertiary effluents in Lake Tahoe water, a good materials balance was obtained but correlation coefficients for the Michaelis-Menten kinetic equation were not statistically significant. In the case of tertiary effluent the

problem arises in part from phosphorus concentrations at the limit of resolving power of analyses and at the margin of growth stimulation.

13. From the calculated percent of inorganic nitrogen in volatile suspended solids produced during pond assays it is concluded that a good materials balance for nitrogen was achieved; and hence that reasonable confidence in the overall results of the nutrient inventory presented is justified.

14. In water as pure initially as Lake Tahoe water the total volatile suspended solids at the end of pond bioassays is an accurate measure of biomass produced.

15. Additional work of a research rather than of a demonstration nature is necessary before the kinetic equation can be successfully applied to algal growth response data.

16. From flask assays of Lake Tahoe water which had been enriched with added nutrients as secondary effluents and allowed to support algal growth prior to flask assay of filtered samples, it was found that a residual growth potential remained in excess of that normally existing in Lake Tahoe water. Consequently algae removal from a waste water could not by itself protect Lake Tahoe.

17. In situations when one nutrient is severely limiting to algal growth a bioassay of the water might lead to a false conclusion concerning its nutrient value. If the limiting factor is phosphorus and Lake Tahoe is, as evidence indicates, nitrogen sensitive, a major growth stimulant (nitrogen) in a discharge to the lake could pass a bioassay test and still do harm to the lake.

18. During cold weather accumulations of nutrients in embayments, keys, and marinas could go undetected and be circulated into the lake to increase its degree of eutrophication.

19. An apparent lack of growth response in a waste water may be due to toxicity at the concentration assayed yet stimulate algal growth when further diluted.

20. Flask assays of surface runoff from relatively undeveloped land areas, as measured by Ward Creek, showed it to be only slightly more capable of stimulating algal growth than Lake Tahoe water.

21. Upper Truckee-Trout Creek, representing an established degree of land development, showed definite effects of human activity as compared to Ward Creek. There is evidence of a discharge of some organic matter into this creek system in about September 1969.

22. During the period of observation, Incline Creek (representing an area undergoing intense development) was consistently more capable of supporting algal growth than was Upper Truckee-Trout Creek.

23. It is concluded that a definite increase in nutrients in creek waters occurs as the level of occupancy and development of land increases, which was evident in both chemical analyses and bioassays.

24. Microscopic analysis of discharges from impounded waters at Lake Tahoe show definite effects of enrichment in terms of amount and diversity of biota.

25. The relative effect of sewage effluents and other sources of nutrients on eutrophication of waters is yet to be determined. Data are being assembled for such an estimate in the Lake Tahoe Basin during the 1970-1971 period of study.

# APPENDIX A

## TABLE A-1

## SIMULTATED SECONDARY EFFLUENT FEED FOR PILOT PONDS

| MACRONUTRIENTS | CONCENTRATION IN FEED (mg/ℓ) |
|---|---|
| $NH_4$ Cl | 76.4 |
| $K_2$ $HPO_4$ | 56.0 |
| Fe $SO_4$ $7H_2O$ | 2.48 |
| Mg $SO_4$ $7H_2O$ | 53.2 |
| **MICRONUTRIENTS** | |
| $Co(NO_3)_2$ $6H_2O$ | 0.012 |
| $(NH_4)_5$ $Mo_7O_{24}$ $4H_2O$ | 0.122 |
| Cu $SO_4$ $5H_2O$ | 0.200 |
| Zn Acetate | 0.280 |
| Mn $Cl_2$ $4H_2O$ | 0.500 |
| $H_3BO_3$ | 5.000 |

## IRON AND TRACE ELEMENTS SUPPLEMENT FOR TERTIARY EFFLUENT FEED FOR PILOT PONDS

| MACRONUTRIENTS | CONCENTRATION IN FEED (mg/ℓ) |
|---|---|
| Fe $SO_4$ $7H_2O$ | 2.48 |
| **MICRONUTRIENTS** | |
| $Co(NO_3)_2$ $6H_2O$ | 0.012 |
| $(NH_4)_6$ $Mo_7O_{24}$ $4H_2O$ | 0.122 |
| Cu $SO_4$ $5H_2O$ | 0.200 |
| Zn Acetate | 0.280 |
| Mn $Cl_2$ $4H_2O$ | 0.500 |
| $H_3BO_3$ | 5.000 |

## TABLE A-2

## COULTER COUNTER VERSUS HAND COUNT COMPARISON

| Sample Type | Date of Sample | Test Organism | Counting Technique | |
|---|---|---|---|---|
| | | | Coulter Counter cell no./$mm^3$ | Hand Count cell no./$mm^3$ |
| MLT[a] | 7-1-69 | S. gracile[f] | 42 | 61 |
| SLT[b] | 7-1-69 | S. gracile | 42 | 55 |
| Ward Creek[c] | 7-1-69 | S. gracile | 46 | 51 |
| Incline Creek[d] | 7-1-69 | S. gracile | 46 | 54 |
| Truckee-Trout Creek[e] | 7-1-69 | S. gracile | 47 | 59 |
| MLT | 7-1-69 | S. cap.[g] | 55 | 65 |
| SLT | 7-1-69 | S. cap. | 57 | 62 |
| Ward Creek | 7-1-69 | S. cap. | 51 | 67 |
| Incline Creek | 7-1-69 | S. cap. | 59 | 68 |
| Truckee-Trout Creek | 7-1-69 | S. cap. | 62 | 61 |

[a] Mid-Lake Tahoe.

[b] Shore-Lake Tahoe.

[c] Ward Creek – Upstream side of bridge on Highway 89.

[d] Incline Creek – Approximately 150 ft upstream from bridge on Lakeshore Boulevard (old Highway 28).

[e] Truckee-Trout Creek – Downstream from the confluence of the Upper Truckee River and Trout Creek across from the Marina of the Tahoe Keys development.

[f] Selenastrum gracile.

[g] Selenastrum capricornutum.

## TABLE A-3

## ANALYTICAL PROCEDURES

1. pH and alkalinity were determined by Standard Methods [4].

   Total alkalinity expressed as mg/ℓ $CaCO_3$ was determined by potentiometric titration. The pH recorded was the initial pH of the water before the acid was added in the titration.

2. Iron.

   The bathophenanthroline method outlined by Strickland and Parsons [5] was used for determination of total soluble iron, including ferrous and ferric iron, and complex ferric and colloidal ferrous forms.

3. BOD [4].

   BOD determinations were performed on unfiltered samples. Lake Tahoe water was used to dilute waste water samples when necessary. Generally no dilution for stream water was required.

4. COD [4].

   COD determinations were performed on unfiltered samples. Because both dilute water samples and waste water were analyzed, oxidation was accomplished by using 0.25 N, 0.05 N, and 0.025 N $K_2Cr_2O_7$.

5. $NO_3$ [5].

   $NO_3$ in water was reduced to $NO_2$ by passing the sample through a column of cadmium filings. The $NO_2$ was then determined.

6. $NO_2$ [5].

   $NO_2$ was determined by colorimetric reaction using sulphanilamide and naphthylethylenediamine solution.

7. $NH_3$ [4].

   $NH_3$ was distilled into a boric acid solution and then nesslerized. Equipment used for the analyses was divided into two sets, one for distillation of samples with relatively high concentrations of ammonia and the other for samples with low levels such as lake and creek samples.

8. Soluble Organic Nitrogen [4,5].

   The sample remaining after $NH_3$ distillation (usually about 24 mℓ) was digested with a sulfuric acid-selenium dioxide mixture. When the digestion was complete, the residue was diluted with $NH_3$-free water, made alkaline, and distilled for the $NH_3$ as reported above.

9. Inorganic Phosphorus (Reactive) [5].

   The sample was mixed with a reagent containing sulfuric acid, ammonium molybdate, and antimony potassium tartrate, adding afterwards ascorbic acid dissolved in ethyl alcohol. The blue color was then read directly from a Beckman spectrophotometer in a 1-cm or 5-cm cell. (The modification used was reported by Richard Armstrong, Institute of Ecology, University of California, Davis.)

10. Total Inorganic Phosphorus [4].

    Total inorganic phosphorus was determined after hydrolysis with a strong solution of sulfuric and nitric acids. A 100 mℓ sample with the acid solution was autoclaved, cooled and then made alkaline. The inorganic phosphorus was then determined as described above.

11. Chlorides [4].

    Chlorides were titrated with mercuric nitrate.

12. Calcium [4].

    Calcium determinations were made by titration with EDTA (ethylenediaminetetraacetic acid).

13. Conductivity [4].

    Specific conductance (μ mho/cm) measurements were done with a conductivity bridge, Model RC 16B2, made by Industrial Instruments, Inc.

TABLE A-4

MODIFIED SKULBERG NUTRIENT MEDIUM [8]

| Macronutrients | Final Concentration (mg/ℓ) | Micronutrients (Adapted from Myers, 1951)* | Final Concentration (mg/ℓ) |
|---|---|---|---|
| $NaNO_3$ | 46.7 | $CO(NO_3)_2 \cdot 6H_2O$ | 0.0012 |
| $Ca(NO_3)_2 \cdot 4H_2O$ | 5.9 | $(NH_4)_6 MO_7O_{24} \cdot 4H_2O$ | 0.0122 |
| $K_2HPO_4$ | 3.1 | $CuSO_4 \cdot 5H_2O$ | 0.0200 |
| $MgSO_4 \cdot 7H_2O$ | 2.5 | $Zn(C_2H_3O_2)$ | 0.0382 |
| $Na_2CO_3$ | 2.1 | $MnCl_2 \cdot 4H_2O$ | 0.050 |
| Fe EDTA ($FeSO_4$ + $Na_2$ EDTA) | 0.2 as Fe | $H_3BO_3$ | 0.50 |

*Myers, J. (1951). "Physiology of the Algae," Ann. Rev. Microbiology, 6:165-180.

# APPENDIX B

### TABLE B-1

### LIGHT MEASUREMENTS AND WEATHER BUREAU DATA

| Date | Assay No. | Solar[a] Radiation Langleys/day | Sky[b,c] Conditions | Precipitation[b] in. | Range of[c] Daily Air Temperature °F | Barometric[b] Pressure in. of Hg | Wind[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0800 | | 1500 | |
| | | | | | | | Velocity mph | Azimuth Direction degrees | Velocity mph | Azimuth Direction degrees |
| 1969 | | | | | | | | | | |
| 7-10 | - | 663 | B-B/C | 0.00 | 46-80 | 30.28 | 0 | | 0 | |
| 7-11 | - | 637 | B-B/C | 0.00 | 42-73 | 30.26 | 0 | | 1 | 250 |
| 7-12 | - | 675 | B | 0.00 | 41-77 | 30.30 | 0 | | 1 | 240 |
| 7-13 | - | 561 | P-C | 0.00 | 42-74 | 30.28 | 0 | | 6 | 220 |
| 7-14 | 1 | 675 | B | 0.00 | 59-78 | 30.20 | 3-6 | 15 | 1 | 220 |
| 7-15 | 1 | 675 | B-B/C | 0.00 | 42-78 | 30.20 | 0 | | 6 | 250 |
| 7-16 | 1 | 650 | B | 0.00 | 42-75 | 30.24 | 0 | | 0 | |
| 7-17 | 1 | 675 | B | 0.00 | 42-78 | 30.30 | 0 | | 7 | 180 |
| 7-18 | 1 | 650 | B | 0.00 | 38-80 | 30.37 | 0 | | 6 | 160 |
| 7-19 | 1 | 624 | P/C | 0.00 | 45-75 | 30.32 | 0 | | 0 | |
| 7-20 | 1 | 637 | P/C | 0.00 | 48-81 | 30.30 | 0 | | 6 | 130 |
| 7-21 | 1 | 637 | B-P/C | 0.00 | 46-85 | 30.30 | 0 | | 1 | 240 |
| 7-22 | 1 | 624 | B | 0.00 | 49-84 | 30.28 | 0 | | 6 | 240 |
| 7-23 | 1 | 522 | C-P/C | 0.00 | 54-85 | 30.30 | 0 | | 6 | 240 |
| 7-24 | 1 | 650 | B-P/C | 0.00 | 49-84 | 30.31 | 0 | | 6 | 200 |
| 7-25 | 1 | 637 | B-P/C | 0.00 | 45-87 | 30.28 | 0 | | 6 | 250 |
| 7-26 | 1 | 624 | B | 0.00 | 47-82 | 30.28 | 0 | | 9 | 150 |
| 7-27 | 1 | 484 | C-P/C | 0.00 | 45-80 | 30.26 | 0 | | - | |
| 7-28 | 1 | 586 | B-P/C | 0.00 | 47-81 | 30.32 | 0 | | 1 | 250 |
| 7-29 | 1 | 624 | C-B | 0.00 | 48-79 | 30.32 | 0 | | 9 | 190 |
| 7-30 | 1 | 650 | B | 0.00 | 41-80 | 30.32 | 0 | | 1 | 250 |
| 7-31 | 1 | 650 | B | 0.00 | 40-81 | 30.36 | 0 | | 6 | 240 |
| 8- 1 | 1 | 586 | B-P/C | 0.00 | 37-81 | 30.20 | 6 | 350 | 0 | |
| 8- 2 | 1 | 612 | B-P/C | 0.00 | 47-81 | 30.25 | 0 | | 9 | 280 |
| 8- 3 | 1 | 573 | B-P/C | 0.00 | 46-85 | 30.29 | 0 | | 9 | 260 |
| 8- 4 | 1 | 637 | B | 0.00 | 44-85 | 30.26 | 6 | 360 | 17 | 230 |
| 8- 5 | 1 | 637 | B | 0.00 | 38-76 | 30.22 | 0 | | 15 | 250 |
| 8- 6 | 1 | 637 | B | 0.00 | 37-79 | 30.20 | 0 | | 6 | 130 |
| 8- 7 | 1 | 650 | B | 0.00 | 35-79 | 30.21 | 0 | | 19 | 210 |
| 8- 8 | 1 | 637 | P/C | 0.00 | 37-80 | 30.21 | 4 | 350 | 9 | 130 |
| 8- 9 | 2 | 573 | C-P/C | 0.00 | 43-82 | 30.20 | 2 | 350 | 0 | |
| 8-10 | 2 | 331 | P/C | 0.00 | 43-83 | 30.20 | 4 | 350 | 6 | 145 |
| 8-11 | 2 | 599 | P/C | 0.00 | 33-79 | 30.23 | 6 | 350 | 11 | 250 |
| 8-12 | 2 | 522 | C-P/C | 0.00 | 35-78 | 30.20 | 4 | 358 | 6 | 170 |
| 8-13 | 2 | 573 | B | 0.00 | 38-78 | 30.19 | 7 | 350 | 0 | |
| 8-14 | 2 | 599 | B | 0.00 | 39-80 | 30.24 | 0 | | 11 | 150 |
| 8-15 | 2 | 624 | B | 0.00 | 44-81 | 30.25 | 0 | | 17 | 200 |
| 8-16 | 2 | 573 | P/C | 0.00 | 42-82 | 30.18 | 0 | | 6 | 130 |
| 8-17 | 2 | 535 | C | 0.00 | 33-81 | 30.14 | 0 | | 11 | 250 |
| 8-18 | 2 | 535 | B-P/C | 0.00 | 40-81 | 30.12 | 0 | | 21 | 210 |
| 8-19 | 2 | 573 | B | 0.00 | 38-74 | 30.14 | 0 | | 11 | 240 |
| 8-20 | 2 | 561 | B | 0.00 | 41-79 | 30.22 | 0 | | 0 | |
| 8-21 | 2 | 561 | C | 0.00 | 49-89 | 30.23 | 4 | 340 | 6 | 140 |
| 8-22 | 2 | 548 | P/C | 0.00 | 44-84 | 30.20 | 5 | 150 | 4 | 160 |
| 8-23 | 3 | 561 | P/C-B | 0.00 | 45-82 | 30.18 | 0 | | 17 | 190 |
| 8-24 | 3 | 612 | P/C-B | 0.00 | 46-81 | 30.21 | 9 | 270 | 17 | 190 |
| 8-25 | 3 | 561 | B | 0.00 | 33-80 | 30.22 | 0 | | 11 | 230 |
| 8-26 | 3 | 573 | B-C | 0.00 | 33-80 | 30.20 | 0 | | 13 | 255 |
| 8-27 | 3 | 573 | B | 0.00 | 36-75 | 30.12 | 11 | 230 | 17 | 240 |
| 8-28 | 3 | 612 | B | 0.00 | 35-78 | 30.09 | 22 | 340 | 22 | 340 |
| 8-29 | 3 | 548 | B | 0.00 | 30-75 | 30.14 | 0 | | 7 | 120 |
| 8-30 | 3 | 561 | B | 0.00 | 35-72 | 30.28 | 4 | 306 | 11 | 210 |
| 8-31 | 3 | 535 | B | 0.00 | 39-78 | 29.95 | 0 | | 11 | 140 |
| 9- 1 | 3 | 497 | B | 0.00 | 36-82 | 30.34 | 0 | | 9 | 130 |
| 9- 2 | 3 | 497 | B-SCT | 0.00 | 40-82 | 30.31 | 0 | | 11 | 230 |
| 9- 3 | 3 | 561 | B-SCT | 0.00 | 29-82 | 30.18 | 0 | | 11 | 240 |
| 9- 4 | 3 | 548 | B-C | 0.00 | 38-80 | 30.11 | 6 | 350 | 9 | 290 |
| 9- 5 | 3 | 561 | P/C | 0.00 | 40-74 | 30.11 | 4 | 340 | 11 | 250 |
| 9- 6 | 3 | 421 | B-C | 0.00 | 45-78 | 30.19 | 0 | | 9 | 240 |
| 9- 7 | 3 | 242 | C | 0.00 | 48-78 | 30.33 | 3 | 330 | 7 | 290 |
| 9- 8 | 4 | 510 | P/C | 0.13 | 49-67 | 30.26 | 4 | 350 | 11 | 220 |
| 9- 9 | 4 | 510 | B | 0.00 | 41-73 | 30.24 | 0 | | 11 | 245 |
| 9-10 | 4 | 522 | B | 0.00 | 38-75 | 30.24 | 0 | | 7 | 130 |
| 9-11 | 4 | 446 | B | 0.00 | 40-75 | 30.29 | 4 | 350 | 6 | 150 |
| 9-12 | 4 | 497 | P/C-B | 0.00 | 39-77 | 30.26 | 0 | | 13 | 240 |
| 9-13 | 4 | 522 | B | 0.00 | 40-77 | 30.20 | 0 | | 11 | 290 |
| 9-14 | 4 | 510 | B | 0.00 | 40-74 | 30.14 | 4 | 340 | 11 | 210 |
| 9-15 | 4 | 510 | B | 0.00 | 39-75 | 30.20 | 11 | 340 | 22 | 200 |
| 9-16 | 4 | 433 | P/C | 0.00 | 38-75 | 30.20 | 6 | 360 | 11 | 240 |
| 9-17 | 4 | 510 | B | 0.00 | 35-69 | 30.21 | 0 | | 11 | 240 |
| 9-18 | 4 | 446 | P/C | 0.00 | 40-69 | 30.21 | 17 | 240 | 22 | 220 |
| 9-19 | 4 | 408 | P/C | 0.00 | 46-64 | 30.17 | 9 | 220 | 13 | 230 |
| 9-20 | 4 | 484 | P/C | 0.00 | 40-62 | 30.03 | 11 | 260 | 11 | 240 |
| 9-21 | 4 | 484 | P/C-B | 0.00 | 31-62 | 30.12 | 6 | 340 | 2 | 210 |
| 9-22 | 4 | 471 | B | 0.00 | 36-62 | 30.24 | 0 | | 6 | 145 |
| 9-23 | 4 | 484 | B | 0.00 | 34-69 | 30.24 | 9 | 350 | 17 | 240 |
| 9-24 | 4 | 459 | B | 0.00 | 31-61 | 30.22 | 0 | | 0 | |
| 9-25 | 4 | 446 | P/C | 0.00 | 42-70 | 30.24 | 0 | | 3 | 220 |
| 9-26 | 4 | 433 | B-P/C | 0.00 | 40-70 | 30.18 | 6 | 240 | 0 | |
| 9-27 | 4 | 459 | B-P/C | 0.00 | 38-72 | 30.14 | 6 | 350 | 17 | 190 |
| 9-28 | 4 | 446 | B-P/C | 0.00 | 34-71 | 30.22 | 0 | | 6 | 110 |
| 9-29 | 4 | 446 | B-P/C | 0.00 | 36-74 | 30.23 | 3 | 340 | 7 | 220 |
| 9-30 | 4 | 433 | B | 0.00 | 35-74 | 30.24 | 0 | | 17 | 220 |

TABLE B-1 (Continued)

| Date | Assay No. | Solar Radiation Langleys/day | Sky Conditions | Precipitation in. | Range of Daily Air Temperature °F | Barometric Pressure in. of Hg | Wind | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0800 | | 1500 | |
| | | | | | | | Velocity mph | Azimuth Direction degree | Velocity mph | Azimuth Direction degree |
| 10- 1 | 4 | 446 | B | 0.00 | 36-73 | 30.14 | 0 | | 20 | 230 |
| 10- 2 | 4 | - | P/C | 0.00 | 32-69 | 30.02 | 0 | | 11 | 350 |
| 10- 3 | 4 | - | P/C | 0.00 | 28-62 | 30.02 | 9 | 7 | 11 | 50 |
| 10- 4 | 5 | - | P/C-B | 0.00 | 30-45 | 30.12 | 9 | 60 | 6 | 120 |
| 10- 5 | 5 | - | P/C | 0.00 | 23-52 | 30.20 | 6 | 340 | 6 | 160 |
| 10- 6 | 5 | 408 | P/C-B | 0.00 | 23-52 | 30.30 | 6 | 350 | 6 | 140 |
| 10- 7 | 5 | 331 | P/C-C | 0.00 | 28-67 | 30.26 | 6 | 350 | 6 | 240 |
| 10- 8 | 5 | 255 | P/C | trace | 29-61 | 30.06 | 22 | 260 | 25 | 250 |
| 10- 9 | 5 | 421 | P/C-C | 0.00 | 29-52 | 30.09 | 6 | 240 | 21 | 240 |
| 10-10 | 5 | 357 | P/C-B | 0.00 | 30-55 | 30.06 | 6 | 260 | 11 | 40 |
| 10-11 | 5 | - | P/C | 0.00 | 31-55 | 30.12 | 6 | 30 | 9 | 130 |
| 10-12 | 5 | 421 | P/C-B | 0.00 | 22-49 | 30.06 | 6 | 340 | 17 | 250 |
| 10-13 | 5 | 370 | P/C-B | 0.00 | 26-50 | 30.00 | 11 | 230 | 17 | 230 |
| 10-14 | 5 | - | P/C-S | 0.02 | 33-48 | 30.08 | 9 | 220 | 6 | 240 |
| 10-15 | 5 | - | R | 0.90 | 32-38 | 30.06 | 6 | 330 | 8 | 200 |
| 10-16 | 5 | - | P/C-R | 0.85 | 40-51 | 30.06 | 17 | 240 | 17 | 250 |
| 10-17 | 5 | - | C | 0.57 | 31-45 | 30.09 | 6 | 220 | 7 | 200 |
| 10-18 | 6 | - | S-C | trace | 28-43 | 29.95 | 0 | | 11 | 350 |
| 10-19 | 6 | - | B | 0.00 | 22-42 | 30.14 | 0 | | 11 | 150 |
| 10-20 | 6 | 408 | P/C-B | 0.00 | 27-40 | 30.36 | 6 | 220 | 8 | 130 |
| 10-21 | 6 | 370 | B | 0.00 | 34-54 | 30.32 | 11 | 80 | 8 | 130 |
| 10-22 | 6 | 357 | C-B | 0.00 | 30-59 | 30.22 | 6 | 350 | 0 | |
| 10-23 | 6 | 319 | C-B | 0.00 | 30-59 | 30.22 | 6 | 350 | 13 | 240 |
| 10-24 | 6 | 357 | P/C-B | 0.00 | 32-58 | 30.18 | 0 | | 17 | 240 |
| 10-25 | 6 | 331 | C-B | 0.00 | 27-57 | 30.25 | 0 | | 6 | 140 |
| 10-26 | 6 | 293 | P/C | 0.00 | 28-56 | 30.24 | 0 | | 6 | 160 |
| 10-27 | 6 | 191 | - | 0.00 | 30-56 | 30.20 | 6 | 10 | - | |
| 10-28 | 6 | 331 | P/C-B | 0.00 | 25-52 | 0 | - | | 0 | |
| 10-29 | 6 | 331 | B | 0.00 | 25-56 | 30.30 | 0 | | 0 | |
| 10-30 | 6 | 319 | B | 0.00 | 27-57 | 30.32 | 0 | | 0 | |
| 10-31 | 6 | 306 | B | 0.00 | 27-55 | 30.30 | 0 | | 0 | |

[a] Solar data obtained from Dr. C. E. Goldman of the University of California, Davis, Fluer du Lac, Lake Tahoe, FWPCA Grant No. WP-01188.

[b] Weather Bureau data obtained from the U. S. Coast Guard Station at Lake Forest, P. O. Box 882, Tahoe City, California.

[c] B/C - Blue Cloudy
B - Blue
P/C - Partly Cloudy
C - Cloudy
R - Rain
S - Snow
SCT - Scattered Clouds

## TABLE B-2

## WATER TEMPERATURE IN PONDS[a]

| Date | Assay No. | Water Temperature | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | High | | Mean | |
| | | °C | °F | °C | °F | °C | °F |
| 1969 | | | | | | | |
| 7-12 | 1 | 17 | 63 | 22 | 72 | 19.8 | 67.6 |
| 7-13 | 1 | 19 | 66 | 23 | 73 | 22.2 | 72.0 |
| 7-14 | 1 | 20 | 68 | 24 | 75 | 21.7 | 71.1 |
| 7-15 | 1 | 20 | 68 | 24 | 75 | 21.8 | 71.2 |
| 7-16 | 1 | 18 | 64 | 22 | 72 | 18.7 | 65.7 |
| 7-17 | 1 | 19 | 66 | 24 | 75 | 21.1 | 70.0 |
| 7-18 | 1 | 20 | 68 | 25 | 77 | 22.4 | 72.3 |
| 7-19 | 1 | 22 | 72 | 26 | 79 | 23.7 | 74.7 |
| 7-20 | 1 | 22 | 72 | 26 | 79 | 25.0 | 77.0 |
| 7-21 | 1 | 22 | 72 | 26 | 79 | 23.8 | 74.8 |
| 7-22 | 1 | 22 | 72 | 27 | 81 | 25.3 | 77.5 |
| 7-23 | 1 | 23 | 73 | 26 | 79 | 24.5 | 76.1 |
| 7-24 | 1 | 23 | 73 | 26 | 79 | 24.1 | 75.4 |
| 7-25 | 1 | 22 | 72 | 26 | 79 | 23.8 | 74.8 |
| 7-26 | 1 | 22 | 72 | 26 | 79 | 23.8 | 74.8 |
| 7-27 | 1 | 22 | 72 | 26 | 79 | 23.4 | 74.1 |
| 7-28 | 1 | 21 | 70 | 25 | 77 | 23.1 | 73.6 |
| 7-29 | 1 | 22 | 72 | 26 | 79 | 23.7 | 74.7 |
| 7-30 | 1 | 21 | 70 | 25 | 77 | 23.0 | 73.4 |
| 7-31 | 1 | 20 | 68 | 24 | 75 | 22.2 | 72.0 |
| 8- 1 | 1 | 19 | 66 | 24 | 75 | 22.6 | 72.7 |
| 8- 2 | 1 | 21 | 70 | 25 | 77 | 23.1 | 73.6 |
| 8- 3 | 1 | 21 | 70 | 25 | 77 | 23.1 | 73.6 |
| 8- 4 | 1 | 21 | 70 | 24 | 75 | 22.6 | 72.7 |
| 8- 5 | 1 | 20 | 68 | 24 | 75 | 21.8 | 71.2 |
| 8- 6 | 1 | 19 | 66 | 23 | 73 | 21.4 | 70.5 |
| 8- 7 | 1 | 19 | 66 | 23 | 73 | 21.1 | 70.0 |
| 8- 8 | 1 | 19 | 66 | 24 | 75 | 21.6 | 70.9 |
| 8- 9 | 2 | 21 | 70 | 25 | 77 | 23.0 | 73.4 |
| 8-10 | 2 | 22 | 72 | 24 | 75 | 23.0 | 73.4 |
| 8-11 | 2 | 21 | 70 | 25 | 77 | 23.2 | 73.8 |
| 8-12 | 2 | 20 | 68 | 24 | 75 | 22.2 | 72.0 |
| 8-13 | 2 | 20 | 68 | 24 | 75 | 22.2 | 72.0 |
| 8-14 | 2 | 21 | 70 | 25 | 77 | 22.8 | 73.0 |
| 8-15 | 2 | 21 | 70 | 25 | 77 | 23.1 | 73.6 |
| 8-16 | 2 | 21 | 70 | 25 | 77 | 23.0 | 73.4 |
| 8-17 | 2 | 21 | 70 | 25 | 77 | 23.4 | 74.1 |
| 8-18 | 2 | 21 | 70 | 24 | 75 | 22.5 | 72.5 |
| 8-19 | 2 | 20 | 68 | 24 | 75 | 22.0 | 71.6 |
| 8-20 | 2 | 20 | 68 | 24 | 75 | 22.2 | 72.0 |
| 8-21 | 2 | 21 | 70 | 25 | 77 | 22.8 | 73.0 |
| 8-22 | 2 | 21 | 70 | 25 | 77 | 22.7 | 72.9 |
| 8-23 | 3 | 21 | 70 | 24 | 75 | 22.4 | 72.3 |
| 8-24 | 3 | 20 | 68 | 23 | 73 | 21.4 | 70.5 |
| 8-25 | 3 | 19 | 66 | 23 | 73 | 20.8 | 69.4 |
| 8-26 | 3 | 18 | 64 | 22 | 72 | 19.9 | 67.8 |
| 8-27 | 3 | 17 | 63 | 22 | 72 | 19.2 | 66.6 |
| 8-28 | 3 | 17 | 63 | 21 | 70 | 18.9 | 66.0 |
| 8-29 | 3 | 16 | 61 | 21 | 70 | 18.8 | 65.8 |
| 8-30 | 3 | 17 | 63 | 22 | 72 | 19.7 | 67.5 |
| 8-31 | 3 | 18 | 64 | 22 | 72 | 20.2 | 68.4 |

TABLE B-2 (Continued)

| Date | Assay No. | Water Temperature | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | High | | Mean | |
| | | °C | °F | °C | °F | °C | °F |
| 9- 1 | 3 | 19 | 66 | 23 | 73 | 20.8 | 69.4 |
| 9- 2 | 3 | 19 | 66 | 23 | 73 | 21.0 | 70.2 |
| 9- 3 | 3 | 19 | 66 | 23 | 73 | 21.0 | 70.2 |
| 9- 4 | 3 | - | - | - | - | - | - |
| 9- 5 | 3 | - | - | - | - | - | - |
| 9- 6 | 3 | - | - | - | - | - | - |
| 9- 7 | 3 | - | - | - | - | - | - |
| 9- 8 | 4 | 16 | 61 | 21 | 70 | 20.3 | 68.5 |
| 9- 9 | 4 | 17 | 63 | 21 | 70 | 24.5 | 76.1 |
| 9-10 | 4 | 18 | 64 | 22 | 72 | 19.9 | 67.8 |
| 9-11 | 4 | 18 | 64 | 21 | 70 | 19.9 | 67.8 |
| 9-12 | 4 | 18 | 64 | 22 | 72 | 20.1 | 68.2 |
| 9-13 | 4 | 18 | 64 | 21 | 70 | 19.6 | 67.3 |
| 9-14 | 4 | 17 | 63 | 20 | 68 | 22.0 | 71.6 |
| 9-15 | 4 | 16 | 61 | 19 | 66 | 17.6 | 63.7 |
| 9-16 | 4 | 16 | 61 | 18 | 64 | 17.1 | 62.8 |
| 9-17 | 4 | 15 | 59 | 19 | 66 | 16.9 | 62.4 |
| 9-18 | 4 | 16 | 61 | 18 | 64 | 19.8 | 67.6 |
| 9-19 | 4 | 16 | 61 | 18 | 64 | 17.0 | 62.6 |
| 9-20 | 4 | 16 | 61 | 18 | 64 | 19.3 | 66.7 |
| 9-21 | 4 | 14 | 57 | 17 | 63 | 15.7 | 60.3 |
| 9-22 | 4 | 14 | 57 | 17 | 63 | 15.2 | 59.4 |
| 9-23 | 4 | 14 | 57 | 17 | 63 | 15.6 | 60.1 |
| 9-24 | 4 | 14 | 57 | 18 | 64 | 17.6 | 63.7 |
| 9-25 | 4 | 15 | 59 | 18 | 64 | 16.7 | 62.1 |
| 9-26 | 4 | 16 | 61 | 19 | 66 | 17.0 | 62.6 |
| 9-27 | 4 | 16 | 61 | 19 | 66 | 18.0 | 64.4 |
| 9-28 | 4 | 15 | 59 | 18 | 64 | 17.1 | 62.8 |
| 9-29 | 4 | 15 | 59 | 18 | 64 | 16.4 | 61.5 |
| 9-30 | 4 | 15 | 59 | 17 | 63 | 16.1 | 61.0 |
| 10- 1 | 4 | 15 | 59 | 18 | 64 | 16.3 | 61.3 |
| 10- 2 | 4 | 15 | 59 | 17 | 63 | 15.1 | 59.2 |
| 10- 3 | 4 | 11 | 52 | 16 | 61 | 14.6 | 58.3 |
| 10- 4 | 5 | 10 | 50 | 12 | 54 | 11.0 | 51.8 |
| 10- 5 | 5 | 9 | 48 | 11 | 52 | 10.3 | 50.5 |
| 10- 6 | 5 | 8 | 46 | 12 | 54 | 11.8 | 53.2 |
| 10- 7 | 5 | 9 | 48 | 12 | 54 | 11.0 | 51.8 |
| 10- 8 | 5 | 11 | 52 | 12 | 54 | 11.2 | 52.2 |
| 10- 9 | 5 | 10 | 50 | 12 | 54 | 11.0 | 51.8 |
| 10-10 | 5 | 10 | 50 | 12 | 54 | 10.8 | 51.4 |
| 10-11 | 5 | 8 | 46 | 10 | 50 | 9.3 | 48.7 |
| 10-12 | 5 | 7 | 45 | 10 | 50 | 8.0 | 46.4 |
| 10-13 | 5 | 7 | 45 | 9 | 48 | 8.0 | 46.4 |
| 10-14 | 5 | 7 | 45 | 8 | 46 | 7.7 | 45.9 |
| 10-15 | 5 | 7 | 45 | 8 | 46 | 7.4 | 45.3 |
| 10-16 | 5 | 7 | 45 | 8 | 46 | 7.7 | 45.9 |
| 10-17 | 5 | 7 | 45 | 8 | 46 | 7.3 | 45.1 |
| 10-18 | 6 | 6 | 43 | 7 | 45 | 6.7 | 44.3 |
| 10-19 | 6 | 5 | 41 | 8 | 46 | 6.6 | 43.9 |
| 10-20 | 6 | 5 | 41 | 8 | 46 | 7.1 | 44.8 |
| 10-21 | 6 | 7 | 45 | 11 | 52 | 9.1 | 48.4 |
| 10-22 | 6 | 9 | 48 | 12 | 54 | 10.5 | 50.9 |
| 10-23 | 6 | 9 | 48 | 12 | 54 | 11.0 | 51.8 |
| 10-24 | 6 | 10 | 50 | 13 | 55 | 11.2 | 52.2 |

TABLE B-2 (Continued)

| Date | Assay No. | Water Temperature | | | | | |
|---|---|---|---|---|---|---|---|
| | | Low | | High | | Mean | |
| | | °C | °F | °C | °F | °C | °F |
| 10-25 | 6 | 10 | 50 | 12 | 54 | 11.2 | 52.2 |
| 10-26 | 6 | 9 | 48 | 11 | 52 | 10.3 | 50.5 |
| 10-27 | 6 | 8 | 46 | 10 | 50 | 9.5 | 49.1 |
| 10-28 | 6 | 8 | 46 | 11 | 52 | 9.3 | 48.7 |
| 10-29 | 6 | 8 | 46 | 10 | 50 | 9.2 | 48.6 |
| 10-30 | 6 | 8 | 46 | 11 | 52 | 8.4 | 47.1 |
| 10-31 | 6 | 9 | 48 | 10 | 50 | 9.4 | 48.9 |

[a] Temperature probe immersed in Pilot Pond No. 8 and connected to a continuous recorder inside the laboratory building.

# APPENDIX C

TABLE C-1

PILOT POND INFLUENT CHEMICAL ANALYSES

| Date of Sampling | Assay No. | Influent Type | Unfiltered Samples | | | | | | | Filtered Samples[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Suspended Solids mg/ℓ | Volatile Suspended Solids mg/ℓ | Nitrogen as N | | Total Phosphorus µg/ℓ | COD mg/ℓ | BOD$_5$ mg/ℓ | Nitrogen as N | | | | Phosphorus as P | | Ca mg/ℓ | Cl mg/ℓ | Fe µg/ℓ | pH | Alk. as CaCO$_3$ mg/ℓ | Cond. (10$^{-6}$) mhos |
| | | | | | Organic µg/ℓ | NH$_3$ µg/ℓ | | | | Organic µg/ℓ | NH$_3$ µg/ℓ | NO$_2$ + NO$_3$ µg/ℓ | Total µg/ℓ | PO$_4$ µg/ℓ | Total µg/ℓ | | | | | | |
| 1969 | | | | | | | | | | | | | | | | | | | | | |
| 7-10 | 1 | STPUD II[b] | 55.29 | 1.28 | 1,250 | 18,400 | 10,000 | 41 | 20 | 1,600 | 20,250 | 4,000 | 25,850 | 7,000 | 8,200 | 26.6 | 26.9 | 41 | 7.8 | 159.5 | 504 |
| 7-14 | 1 | SLTW[c] | 1.48 | | 68 | 48 | 13 | | | 82 | 52 | 4 | 158 | 8 | | | | | 7.6 | | 105 |
| 7-16 | 1 | SLTW | 1.37 | 0.38 | | | | | | | 7 | 3 | - | 4 | | | | <1 | | | |
| 7-17 | 1 | SLTW | | | | | 59 | | | | | | | | 43 | | | | | | |
| 7-18 | 1 | SLTW | 1.53 | 0.51 | | | | | | | 13 | 4 | - | 9 | 16 | | | | | | |
| 7-21 | 1 | SLTW | 1.75 | 0.59 | | | | | | 45 | 77 | 7 | 129 | 5 | 12 | | | | 7.8 | | 93 |
| 7-23 | 1 | SLTW | 0.80 | 0.34 | | | | | | | 56 | 3 | - | 3 | 3 | | | | 7.8 | | 92 |
| 7-23 | 1 | STPUD II | 10.49 | 5.77 | 3,200 | 16,000 | 8,200 | | 13 | 3,400 | 16,500 | 6,100 | 26,000 | 8,160 | 8,400 | 30.8 | 27.0 | | | | |
| 7-25 | 1 | SLTW | 0.94 | 0.45 | | | | | | | 55 | 11 | - | 4 | 17 | | | | 7.8 | | |
| 7-28 | 1 | SLTW | 0.66 | 0.46 | | | | | | 25 | <5 | 2 | 30 | 3 | 4 | | | | 7.7 | | 96 |
| 7-30 | 1 | SLTW | 0.56 | | | | | | | | 28 | 6 | - | 2 | 13 | | | | 7.6 | | |
| 7-31 | 1 | STPUD II | 23.95 | 22.21 | 1,280 | 20,000 | 12,600 | 76 | 12 | 1,045 | 16,100 | 1,300 | 18,445 | 11,600 | 12,240 | 30.0 | 28.1 | 58 | 8.1 | 174.0 | 480 |
| 8- 1 | 1 | SLTW | 0.64 | 0.41 | | | | | | | 25 | 7 | | 2 | 4 | | | | 7.7 | | |
| 8- 4 | 1 | SLTW | 0.40 | 0.24 | | | | | | 27 | <5 | 4 | 34 | 3 | 5 | | | | 7.4 | | 90 |
| 8- 5 | 1 | SLTW | 0.55 | 0.34 | | | | | | | | | | | | | | | | | |
| 8- 6 | 1 | SLTW | 0.58 | 0.34 | | | | | | | 9 | 8 | - | 3 | 57 | | | | 7.7 | | |
| 8- 7 | 1 | SLTW | 0.37 | | | | | | | | | | | | | | | | | | |
| 8- 8 | 1 | SLTW | 0.48 | 0.20 | 60 | 31 | 13 | | | 51 | 31 | 15 | 97 | 1 | 27 | | | | 7.8 | | 94 |
| 8-11 | 2 | SLTW | 0.52 | 0.25 | | | | | | 94 | 27 | 6 | 127 | 6 | 25 | | | 2 | 7.6 | | 118 |
| 8-12 | 2 | STPUD II | 30.85 | 29.35 | 4,710 | 25,240 | 13,400 | 69 | | 4,560 | 25,620 | 270 | 30,460 | 11,800 | 12,400 | 33.6 | 22.0 | 58 | 7.8 | 194.7 | 500 |
| 8-13 | 2 | SLTW | 0.40 | | | | | | | | 20 | 12 | - | 1 | 5 | | | | 7.9 | | |
| 8-15 | 2 | SLTW | 0.35 | 0.23 | | | | | | | 46 | 6 | - | 2 | 2 | | | | 8.0 | | |
| 8-18 | 2 | SLTW | 0.36 | 0.19 | | | | | | | 49 | 21 | - | 4 | 37 | | | | 8.0 | | 98 |
| 8-19 | 2 | SLTW | 0.42 | 0.26 | | | | | | | | | | | | | | | | | |
| 8-19 | 2 | STPUD II | 6.90 | 6.13 | 1,462 | 19,620 | 7,660 | | 7 | 1,615 | 27,600 | 3,620 | 32,855 | 7,140 | 7,660 | 38.8 | 24.6 | 16 | 8.1 | 176.5 | 485 |
| 8-20 | 2 | SLTW | 0.24 | 0.22 | | | | | | | 60 | 8 | - | 3 | 6 | | | <1 | 7.9 | | |
| 8-21 | 2 | SLTW | 0.44 | | | | | | | | | | | | | | | | 8.0 | | |
| 8-22 | 2 | SLTW | 0.43 | 0.26 | 52 | 21 | 7 | | | 74 | 44 | 7 | 125 | 4 | 8 | | | | 8.0 | | 90 |
| 8-25 | 3 | SLTW | 0.37 | 0.24 | | | | | | 40 | 31 | 15 | 93 | 4 | 13 | | | 6 | 7.9 | | 91 |
| 8-26 | 3 | STPUD II | 4.69 | 4.09 | 624 | 23,720 | 9,700 | 25 | | 786 | 22,664 | 2,730 | 26,176 | 9,000 | 9,500 | 32.2 | 25.4 | 38 | 8.0 | 188.0 | 535 |
| 8-27 | 3 | SLTW | 0.39 | | | | | | | | 46 | 16 | - | 4 | 5 | | | | 7.5 | | |
| 8-29 | 3 | SLTW | 0.37 | 0.32 | | | | | | | 18 | 19 | - | 4 | 21 | | | | 7.8 | | 90 |
| 9- 1 | 3 | SLTW | 0.38 | 0.31 | | | | | | 48 | 36 | 13 | 97 | 6 | 7 | | | | | | |
| 9- 2 | 3 | SLTW | 0.44 | | | | | | | | | | | | | | | 8 | | | |
| 9- 3 | 3 | SLTW | 0.39 | 0.27 | 122 | 18 | 6 | | | 89 | 25 | 5 | 119 | 3 | 7 | | | | 7.9 | | 89 |
| 9- 8 | 4 | STPUD III[d] | 1.97 | 1.09 | 426 | 11,627 | 152 | 10 | | 405 | 11.579 | 840 | 12,824 | 132 | 146 | 46.2 | 28.3 | 7 | 8.2 | 203.8 | 500 |
| 9- 9 | 4 | SLTW | | | 98 | 80 | 25 | | | 67 | 62 | 7 | 136 | 3 | 6 | | | | 7.9 | | 86 |
| 9-10 | 4 | SLTW | 0.48 | 0.27 | | | | | | | 28 | 11 | - | 3 | 4 | | | | 7.9 | | 88 |
| 9-12 | 4 | SLTW | 0.51 | 0.30 | | | | | | | 20 | 14 | - | 3 | | | | | 7.6 | | |
| 9-15 | 4 | SLTW | 0.61 | | | | | | | 5 | 57 | 3 | 65 | 5 | 6 | | | 6 | | | |
| 9-17 | 4 | SLTW | 0.30 | | | | | | | | 18 | 18 | - | 3 | 10 | | | | | | |
| 9-19 | 4 | SLTW | | | | | | | | | <5 | <1 | - | 5 | | | | | 7.7 | | |
| 9-19 | 4 | STPUD III | 0.69 | 0.51 | 455 | 11,910 | 142 | 44 | | 532 | 11,390 | | | 77 | 118 | 74.2 | 26.4 | 19 | 8.0 | 255.2 | 560 |
| 9-22 | 4 | SLTW | | | | | | | | 52 | 36 | 14 | 82 | 3 | 22 | | | | 8.0 | | 83 |
| 9-24 | 4 | SLTW | 0.62 | 0.39 | | | | | | | <5 | 7 | - | 7 | 8 | | | | 7.4 | | |
| 9-26 | 4 | SLTW | 0.40 | | | | | | | | 10 | 10 | - | 5 | 5 | | | | 7.6 | | |
| 9-26 | 4 | STPUD III | 0.44 | 0.36 | 383 | 12,490 | 26 | 29 | 2 | 378 | 14,850 | 50 | 15,258 | 50 | 62 | 64.6 | 22.4 | 4 | 7.9 | 238.0 | 570 |
| 9-29 | 4 | SLTW | 0.54 | 0.26 | | | | | | 58 | 15 | 30 | 105 | 11 | 17 | | | | 7.9 | | 88 |
| 9-30 | 4 | SLTW | 0.57 | 0.28 | | | | | | | | | | | | | | | | | |
| 10- 1 | 4 | SLTW | 0.52 | 0.24 | | | | | | | 24 | 13 | - | 2 | 15 | | | 50 | 7.7 | | |
| 10- 2 | 4 | SLTW | 0.52 | | | | | | | | | | | | | | | | | | |
| 10- 3 | 4 | SLTW | 0.92 | 0.48 | 16 | 18 | 3 | | | 79 | 14 | 2 | 95 | 3 | 5 | | | | 7.4 | | |

TABLE C-1 (Continued)

| Date of Sampling | Assay No. | Influent Type | Unfiltered Samples | | | | | | | Filtered Samples | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Suspended Solids | Volatile Suspended Solids | Nitrogen as N | | Total Phosphorus | COD | BOD$_5$ | Nitrogen as N | | | | Phosphorus as P | | Ca | Cl | Fe | pH | Alk. as CaCO$_3$ | Cond (10$^{-6}$) |
| | | | mg/ℓ | mg/ℓ | Organic μg/ℓ | NH$_3$ μg/ℓ | μg/ℓ | mg/ℓ | mg/ℓ | Organic μg/ℓ | NH$_3$ μg/ℓ | NO$_2$ + NO$_3$ μg/ℓ | Total μg/ℓ | PO$_4$ μg/ℓ | Total μg/ℓ | mg/ℓ | mg/ℓ | μg/ℓ | | mg/ℓ | mhos |
| 10- 3 | 5 | STPUD III | 0.94 | 0.84 | 489 | 12,200 | | 10 | | 522 | 9,810 | 460 | 10,792 | 41 | 79 | 51.2 | 20.7 | 15 | 8.1 | 203.2 | 480 |
| 10- 6 | 5 | SLTW | 0.61 | 0.23 | | | | | | 60 | 6 | 21 | 87 | 2 | 57 | | | | 7.1 | | |
| 10- 8 | 5 | SLTW | 9.62$^e$ | | | | | | | | 20 | 26 | - | 5 | 5 | | | | 7.4 | | |
| 10- 8 | 5 | STPUD III | 1.14 | 0.94 | 527 | 16,990 | 334 | 20 | <1 | 479 | 13,880 | 630 | 14,989 | 295 | 297 | 38.7 | 26.4 | 9 | 8.2 | 198.0 | 470 |
| 10-10 | 5 | SLTW | 0.86 | | | | | | | | <5 | 15 | - | 2 | 13 | | | | 8.0 | | |
| 10-13 | 5 | SLTW | 2.66 | 0.68 | | | | | | 77 | 4 | 35 | 116 | 2 | 6 | | | | 7.6 | | 83 |
| 10-13 | 5 | STPUD III | | | 297 | 22,000 | 160 | | | 383 | 19,620 | 433 | 20,436 | 146 | 150 | | | | | | |
| 10-14 | 5 | SLTW | 0.98 | 0.39 | | | | | | | | | | | | | | | | | |
| 10-15 | 5 | SLTW | 0.58 | | | | | | | | 30 | 24 | - | 4 | 13 | | | | 7.7 | | |
| 10-16 | 5 | SLTW | 1.23 | 1.06 | | | | | | | | | | | | | | | | | |
| 10-17 | 5 | SLTW | 0.64 | 0.28 | 48 | 20 | 7 | | | 41 | 38 | 13 | 92 | 3 | 6 | | | | 7.7 | | |
| 10-17 | 6 | STPUD III | 0.52 | 0.52 | 411 | 15,740 | 134 | 31 | | 503 | 15,310 | 215 | 16,028 | 104 | 134 | | | | 8.2 | 282.0 | 650 |
| 10-20 | 6 | SLTW | 3.89 | 0.83 | | | | | | <5 | 18 | 23 | 44 | 4 | 8 | | | | 8.0 | | 85 |
| 10-20 | 6 | STPUD III | 1.00 | 0.89 | 310 | 18,800 | 392 | 31 | <1 | 169 | 18,770 | 120 | 19,059 | 364 | 409 | 62.0 | 28.1 | 2 | 7.8 | 268.3 | 610 |
| 10-22 | 6 | SLTW | 0.77 | | | | | | | | <5 | 13 | - | 3 | 10 | | | | 8.2 | | |
| 10-24 | 6 | SLTW | 1.10 | 0.26 | | | | | | | 9 | 6 | - | 2 | 5 | | | | 8.0 | | |
| 10-24 | 6 | STPUD III | 0.54 | 0.42 | 489 | 15,590 | 157 | 60 | 4 | 627 | 16,840 | 60 | 17,527 | 148 | 168 | 79.2 | 34.3 | 9 | 8.0 | 281.5 | 575 |
| 10-27 | 6 | SLTW | 0.72 | 0.22 | | | | | | 20 | <5 | 12 | 34 | 4 | 5 | | | | 8.2 | | 86 |
| 10-27 | 6 | STPUD III | 1.47 | 1.28 | 278 | 16,020 | 153 | 58 | 10 | 474 | 15,780 | 140 | 16,394 | 110 | 151 | 69.8 | 29.5 | <1 | 8.1 | 258.2 | 525 |
| 10-28 | 6 | SLTW | 0.77 | 0.32 | | | | | | | | | | | | | | | | | |
| 10-29 | 6 | SLTW | 1.33 | 0.50 | | | | | | | 27 | 25 | - | 3 | | | | | 7.4 | | |
| 10-30 | 6 | SLTW | 0.87 | | | | | | | | | | | | | | | | | | |
| 10-31 | 6 | SLTW | 0.83 | 0.20 | 32 | 10 | 6 | | | 26 | <5 | 22 | 50 | 2 | 11 | | | | 7.9 | | |

[a] Effluent from South Tahoe Public Utility District's (STPUD) Waste Treatment Plant was passed through 0.45 μ Millipore filters. Shore-Lake Tahoe Water (SLTW) was passed through GF/C filters.

[b] STPUD II – South Tahoe Public Utility District's Waste Treatment Plant's secondary (II) effluent.

[c] SLTW – Shore-Lake Tahoe Water pumped to the pilot ponds through 2,000 ft of 2 in. PVC pipe from a location near the U. S. Coast Guard Pier.

[d] STPUD III – South Tahoe Public Utility District's (STPUD) Waste Treatment Plant's tertiary (III) effluent before chlorination.

[e] Stormy day.

## TABLE C-2

## CHEMICAL ANALYSES OF SHORE AND MID-LAKE TAHOE

| Date | Sample Location | Unfiltered Sample COD mg/ℓ | 0.45 μ Millipore Filtered Samples | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nitrogen as N | | | | | Phosphorus as P | | Ca mg/ℓ | Cl mg/ℓ | Fe μg/ℓ | pH | Alk. as $CaCO_3$ mg/ℓ | Cond. $(10^{-6})$ mhos |
| | | | Organic μg/ℓ | $NH_3$ μg/ℓ | $NO_2$ μg/ℓ | $NO_3$ μg/ℓ | Total μg/ℓ | $PO_4$ μg/ℓ | Total μg/ℓ | | | | | | |
| 1969 | | | | | | | | | | | | | | | |
| 1- 3 | MLT[a] | - | <5 | 20 | 6 | 1 | 30 | <1 | 1 | - | 1.8 | <1 | 7.7 | 41.3 | 75 |
| 1- 4 | SLT[b] | - | 75 | 50 | 5 | 1 | 131 | <1 | <1 | - | 1.8 | <1 | 7.6 | 40.7 | 77 |
| 2- 4 | MLT | <1 | <5 | 9 | 6 | 15 | 32 | 5 | 5 | - | 1.5 | 18 | 7.9 | 42.0 | 75 |
| 2- 4 | SLT | <1 | 56 | 20 | 5 | 12 | 93 | 9 | 18 | - | 2.3 | 25 | 8.0 | 43.3 | 83 |
| 3- 6 | SLT | <1 | 87 | 13 | <1 | 10 | 110 | 1 | 5 | 10.0 | 2.6 | <1 | 8.1 | 43.2 | 83 |
| 3-15 | MLT | <1 | 86 | 32 | <1 | 8 | 126 | <1 | <1 | 11.9 | 1.4 | <1 | 7.7 | 40.8 | 78 |
| 4- 1 | SLT | <1 | 82 | 62 | 8 | 17 | 169 | 3 | 6 | 11.9 | 3.8 | <1 | 7.5 | 40.2 | 85 |
| 5- 6 | MLT | 14[c] | 40 | 16 | 3 | 2 | 61 | 4 | 5 | 10.0 | 1.8 | - | 7.6 | 41.8 | 70 |
| 5- 6 | SLT | 11[c] | 75 | <5 | 3 | 4 | 84 | 5 | 6 | 8.4 | 1.7 | - | 7.3 | 36.5 | 63 |
| 6- 4 | SLT | - | 60 | <5 | 3 | 7 | 72 | <1 | 22 | 7.8 | 1.3 | 13 | 7.6 | 41.0 | 90 |
| 6- 9 | MLT | - | 75 | <5 | 6 | <1 | 84 | 2 | 4 | 9.5 | 1.8 | 5 | 7.5 | 39.9 | 76 |
| 7- 1 | MLT | - | 34 | 10 | 6 | 1 | 51 | 2 | 7 | 9.0 | 1.4 | <1 | 7.6 | 40.3 | 84 |
| 7- 1 | SLT | - | 30 | 15 | 5 | 6 | 56 | 4 | 9 | 9.3 | 1.5 | <1 | 7.4 | 40.3 | 84 |
| 8- 5 | MLT | 21 | 162 | 25 | 2 | 3 | 192 | 2 | 9 | 9.8 | 1.4 | <1 | 7.7 | 38.6 | 86 |
| 8- 5 | SLT | <1 | 198 | 30 | 1 | 4 | 233 | 3 | 9 | 10.3 | 1.4 | <1 | 7.7 | 37.9 | 81 |
| 9-10 | MLT | - | 130 | 36 | 2 | 10 | 178 | 4 | 9 | 7.9 | 1.5 | <1 | 7.9 | 41.6 | 82 |
| 9-10 | SLT | - | 165 | 30 | 2 | 15 | 212 | 3 | 6 | 7.0 | 1.5 | <1 | 8.0 | 42.0 | 80 |
| 10- 6 | MLT | 6 | 125 | 5 | 2 | 17 | 149 | 6 | 12 | 8.6 | 1.3 | <1 | 7.8 | 41.8 | 77 |
| 10- 6 | SLT | 4 | 132 | 26 | 3 | 20 | 181 | 6 | 8 | 9.5 | 1.4 | 2 | 7.9 | 40.6 | 80 |
| 11- 4 | MLT | - | 98 | 16 | 6 | 2 | 122 | 7 | 7 | 8.7 | 1.2 | <1 | 7.7 | 42.3 | 86 |
| 11- 6 | SLT | - | 244 | 30 | 6 | 2 | 282 | 4 | 7 | 8.7 | 1.4 | <1 | 7.6 | 41.8 | 88 |
| 12-12 | SLT | - | 84 | 10 | 4 | <1 | 98 | 5 | 9 | 9.5 | 0.8 | 5 | 7.7 | 42.4 | 72 |
| 12-14 | MLT | - | <5 | 40 | 3 | <1 | 44 | 37 | 38 | 7.5 | 1.0 | <1 | 7.5 | 35.9 | 76 |

[a] Mid-Lake Tahoe.

[b] Shore-Lake Tahoe – samples from U. S. Coast Guard Pier.

[c] Malfunctioning equipment.

TABLE C-3

SHORE AND MID-LAKE TAHOE, CREEKS, AND SPECIAL MEDIA BIOMASS MEASUREMENTS[a]* (FLASK ASSAY)

| Date of Sampling | Sample Type | Concentration (% of Sample) % | Test Cell Organism | Counting Method | Detention Time θ 1 day Coun[illegible] cell [illegible]m$^3$ | 3 day Counts cell no./mm$^3$ | 5 day Counts cell no./mm$^3$ | Suspended[b] Solids mg/ℓ | pH[c] |
|---|---|---|---|---|---|---|---|---|---|
| 1969 | | | | | | | | | |
| 1- 3 | MLT[d] | 100 | S. gracile[e] | Hand | 40 | 47 | 69 | 3.51 | |
| | Ward[f] | 50 | | | 52 | 56 | 73 | 4.71 | |
| | | 100 | | | 48 | 72 | 155 | 3.29 | |
| | Incline[g] | 50 | | | 56 | 54 | 68 | 4.02 | |
| | | 100 | | | 56 | 53 | 155 | 5.56 | |
| | Tr. Tr.[h] | 50 | | | 55 | 86 | 209 | 8.28 | |
| | | 100 | | | 60 | 155 | 365 | 11.82 | |
| 1- 4 | SLT[i] | 100 | | | 41 | 56 | 104 | 4.52 | |
| 1-29 | Sp. Media[j] | 100 | | | 42 | 118 | 462 | 14.89 | |
| 2- 4 | MLT | 100 | | | 30 | 40 | 54 | | |
| | SLT | 100 | | | 35 | 41 | 148 | | |
| | Ward | 50 | | | 29 | 125 | 107 | | |
| | | 100 | | | 28 | 103 | 181 | | |
| | Incline | 50 | | | 36 | 180 | 1429 | | |
| | | 100 | | | 38 | 176 | 1812 | | |
| | Tr. Tr. | 50 | | | 46 | 151 | 230 | | |
| | | 100 | | | 70 | 254 | 1072 | | |
| 3- 2 | Sp. Media | 100 | | | 36 | 158 | 860 | | |
| 3- 4 | Ward | 50 | | | 41 | 120 | 168 | | |
| | | 100 | | | 49 | 200 | 190 | | |
| | Incline | 50 | | | 60 | 154 | 233 | | |
| | | 100 | | | 92 | 333 | 395 | | |
| | Tr. Tr. | 50 | | | 62 | 158 | 223 | | |
| | | 100 | | | 66 | 198 | 265 | | |
| 3- 6 | SLT | 100 | | | 45 | 88 | 163 | | |
| 3-15 | MLT | 100 | | | 43 | 96 | 185 | | |

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*For footnotes a through n see page 91.

TABLE C-3 (Continued)

| Date of Sampling | Sample Type | Concentration (% of Sample) % | Test Cell Organism | Counting Method | Detention Time θ | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 day | 3 day | 5 day | | |
| | | | | | Counts cell no./mm³ | Counts cell no./mm³ | Counts cell no./mm³ | Suspended Solids mg/ℓ | pH |
| 4- 1 | SLT | 100 | *S. gracile* | Hand | 45 | 126 | 182 | | |
| | Ward | 50 | | | 40 | 92 | 140 | | |
| | | 100 | | | 36 | 120 | 162 | | |
| | Incline | 50 | | | 41 | 126 | 667 | | |
| | | 100 | | | 45 | 170 | 974 | | |
| | Tr. Tr. | 50 | | | 39 | 130 | 134 | | |
| | | 100 | | | 49 | 117 | 140 | | |
| 4-13 | Sp. Media | 100 | | | 48 | 168 | 800 | | |
| 5- 6 | MLT | 100 | | | 60 | 94 | 96 | 4.97 | 7.4 |
| | SLT | 100 | | | 56 | 200 | 223 | 6.44 | 7.4 |
| | Ward | 50 | | | 68 | 135 | 143 | 7.20 | 7.4 |
| | | 100 | | | 67 | 172 | 186 | 9.86 | 7.4 |
| | Incline | 50 | | | 47 | 174 | 244 | 8.08 | 7.4 |
| | | 100 | | | 69 | 269 | 383 | 12.29 | 7.4 |
| | Tr. Tr. | 50 | | | 66 | 167 | 137 | 6.38 | 7.4 |
| | | 100 | | | 83 | 200 | 250 | 7.56 | 7.4 |
| 6- 4 | SLT | 100 | | | 42 | 56 | 103 | 4.18 | 7.2 |
| | Ward | 50 | | | 43 | 72 | 89 | 4.71 | 7.3 |
| | | 100 | | | 41 | 111 | 109 | 7.38 | 7.3 |
| | Incline | 50 | | | 39 | 96 | 124 | 4.83 | 7.3 |
| | | 100 | | | 30 | 109 | 130 | 8.50 | 7.4 |
| | Tr. Tr. | 50 | | | 38 | 111 | 76 | 5.18 | 7.4 |
| | | 100 | | | 41 | 87 | 242 | 5.00 | 7.4 |
| 6- 9 | MLT | 100 | | | 52 | 52 | 69 | 3.13 | 7.1 |
| 7- 1 | MLT | 100 | *S. gracile* | Coulter Counter | 42 | 95 | 129 | 5.02 | 7.4 |
| | SLT | 100 | | | 42 | 102 | 134 | 5.24 | 7.6 |
| | Ward | 100 | | | 46 | 113 | 127 | 5.69 | 7.4 |
| | Incline | 100 | | | 46 | 137 | 172 | 5.49 | 7.4 |
| | Tr. Tr. | 100 | | | 47 | 126 | 156 | 4.69 | 7.0 |

TABLE C-3 (Continued)

| Date of Sampling | Sample Type | Concentration (% of Sample) % | Test Cell Organism | Counting Method | Detention Time θ 1 day Counts cell no./mm³ | 3 day Counts cell no./mm³ | 5 day Counts cell no./mm³ | Suspended Solids mg/ℓ | pH |
|---|---|---|---|---|---|---|---|---|---|
| 7- 1 | MLT | 100 | *S. cap.*[k] | Coulter Counter | 55 | 57 | 66 | 1.98 | 7.8 |
| | SLT | 100 | | | 57 | 74 | 90 | 2.42 | 7.7 |
| | Ward | 100 | | | 51 | 79 | 85 | 2.49 | 7.6 |
| | Incline | 100 | | | 59 | 138 | 172 | 3.07 | 7.6 |
| | Tr. Tr. | 100 | | | 62 | 99 | 120 | 3.00 | 7.2 |
| 8- 5 | MLT | 100 | | | 52 | 58 | 62 | 1.70 | 8.0 |
| | SLT | 100 | | | 63 | 95 | 98 | 2.76 | 7.9 |
| | Ward | 100 | | | 73 | 235 | 236 | 5.52 | 7.8 |
| | Incline | 100 | | | 74 | 239 | 272 | 8.54 | 7.7 |
| | Tr. Tr. | 100 | | | 67 | 104 | 103 | 3.27 | 7.7 |
| 8- 8 | Incline A[l] | 100 | | | 71 | 152 | 214 | 5.09 | 8.0 |
| | Incline B | 100 | | | 85 | 346 | 503 | 9.82 | 7.9 |
| | Incline C | 100 | | | 116 | 331 | 397 | 8.46 | 7.8 |
| 9-10 | MLT | 100 | *S. cap.*[m] | Coulter Counter | 72 | 122 | 219 | 0.70 | |
| | SLT | 100 | | | 73 | 154 | 136 | 1.16 | |
| | Ward | 100 | | | 72 | 256 | 316 | 1.13 | |
| | Incline | 100 | | | 146 | 575 | 1092 | 6.25 | |
| | Tr. Tr. | 100 | | | 121 | 386 | 525 | 1.82 | |
| 10- 2 | Ward | 100 | | | 46 | 203 | 283 | 2.15 | 8.0 |
| | Incline | 100 | | | 49 | 161 | 177 | 1.47 | 7.9 |
| | Tr. Tr. | 100 | | | 57 | 351 | 411 | 1.95 | 7.9 |
| 10- 6 | MLT | 100 | | | 46 | 49 | 100 | 1.07 | 8.4 |
| | SLT | 100 | | | 51 | 62 | 102 | 1.15 | 8.1 |
| 11- 6 | SLT | 100 | *S. cap.*[n] | Coulter Counter | 65 | 205 | 264 | 1.61 | 7.8 |
| | Ward | 100 | | | 53 | 132 | 274 | 2.79 | 7.7 |
| | Incline | 100 | | | 71 | 185 | 263 | 2.03 | 7.7 |
| | Tr. Tr. | 100 | | | 58 | 169 | 221 | 2.08 | 7.6 |
| | General | 100 | | | 55 | 168 | 328 | 3.32 | 7.7 |
| | MLT | 100 | | | 59 | 191 | 203 | 2.47 | 7.8 |
| 12-12 | SLT | 100 | | | 71 | 120 | 140 | 2.30 | 7.8 |
| 12-14 | MLT | 100 | | | 68 | 108 | 133 | 2.26 | 7.5 |

TABLE C-3 (Continued)

[a] Samples passed through a 0.45 μ Millipore filter and then inoculated with a culture of either Selenastrum gracile or Selenastrum capricornutum at a concentration of 50 cells/mm$^3$.

[b] Analyses performed by GF/C filters.

[c] Analyzed on the culture after it passed through the GF/C filter.

[d] MLT – Mid-Lake Tahoe.

[e] S. gracile – Selenastrum gracile.

[f] Ward – Ward Creek sampled at the upstream side of bridge on Highway 89.

[g] Incline – Incline Creek sampled approximately 150 ft upstream from bridge on Lakeshore Boulevard (old Highway 28).

[h] Tr. Tr. – Upper Truckee-Trout River; sampled downstream from the confluence of the Upper Truckee River and Trout Creek across from the Marina of the Tahoe Keys Development.

[i] SLT – Shore-Lake Tahoe; sampled from the U. S. Coast Guard Pier.

[j] Sp. Media – Special Media – ten percent Modified Skulberg Nutrient Media (see Table A-4).

[k] S. cap. – Selenastrum capricornutum.

[l] Sampling point locations:
A – Above Incline Village in an undeveloped and undisturbed area.
B – Below an area under construction at the time the sample was collected.
C – Regular sampling point.

[m] Culture test cell organism was contaminated with a "Chlorella" type organism. Only a small percentage of S. capricornutum was observed.

[n] New pure culture of S. capricornutum.

# APPENDIX D

TABLE D-1

PILOT POND ANALYSES

| Date | Pond Detention Time # | Pond No. | Influent Description | Temperature | Unfiltered Samples |  |  |  |  | GF/C Filtered Sample |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Suspended Solids | Volatile Suspended Solids | Nitrogen as N |  | Total Phosphorus | Nitrogen as N |  |  |  | Phosphorus as P |  | Fe | Cond. $(10^{-6})$ | pH |
|  |  |  |  |  |  |  | Organic | $NH_3$ |  | Organic | $NH_3$ | $NO_2$-$NO_3$ | Total | $PO_4$ | Total |  |  |  |
|  | days |  |  | °C | mg/ℓ | mg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | µg/ℓ | mhos |  |
| 1969<br>7-14 | 8<br>Assay<br>No.<br>1 | 1 | LTW[a] | 21.7 | 0.76 | 0.42 | 88 | 32 | 32 | 60 | 25 | 4 | 89 |  |  |  | 183 | 7.2 |
|  |  | 2 | 0.1% II |  | 1.01 | 0.15 | 85 | 25 | 32 | 79 | <5 | 2 | 84 |  |  |  | 158 | 7.4 |
|  |  | 3 | 1% II |  | 0.98 | 0.60 | 86 | 155 | 83 | 84 | 116 | 30 | 230 |  |  |  | 100 | 7.5 |
|  |  | 4 | 1% S-II |  | 0.92 | 0.43 | 84 | 330 | 300 | 104 | 325 | <1 | 430 |  |  |  | 99 | 7.6 |
|  |  | 5 | LTW |  | 0.69 | 0.69 | 72 | 39 | 13 | 93 | <5 | 3 | 98 |  |  |  | 98 | 7.6 |
|  |  | 6 | 0.1% II |  | 0.75 | 0.25 | 54 | 26 | 232 | 60 | <5 | 3 | 66 |  |  |  | 96 | 7.6 |
|  |  | 7 | 1% II |  | 0.81 |  | 100 | 160 | 73 | 120 | 72 | 25 | 217 |  |  |  | 96 | 7.6 |
|  |  | 8 | 1% S-II |  | 0.81 | 0.49 | 66 | 355 | 185 | 86 | 325 | <1 | 412 |  |  |  | 98 | 7.[illegible] |
| 7-16 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 18.7 | 2.15 | 0.60 |  |  |  |  | 30 | <1 |  |  |  | <1 |  |  |
|  |  | 2 | 0.1% II |  | 2.57 | 0.84 |  |  |  |  | 40 | <1 |  |  |  | <1 |  |  |
|  |  | 3 | 1% II |  | 2.73 | 1.33 |  |  |  |  | 56 | 23 |  |  |  | <1 |  |  |
|  |  | 4 | 1% S-II |  | 3.40 | 1.18 |  |  |  |  | 92 | <1 |  |  |  | 12 |  |  |
|  |  | 5 | LTW |  | 1.76 | 0.54 |  |  |  |  | 9 | <1 |  |  |  | 34 |  |  |
|  |  | 6 | 0.1% II |  | 1.66 | 0.70 |  |  |  |  | 31 | <1 |  |  |  | 2 |  |  |
|  |  | 7 | 1% II |  | 3.06 | 1.38 |  |  |  |  | 31 | 17 |  |  |  | <1 |  |  |
|  |  | 8 | 1% S-II |  | 2.46 | 1.14 |  |  |  |  | 86 | <1 |  |  |  | 2 |  |  |
| 7-17 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 21.1 |  |  |  |  | 19 |  |  |  |  |  | 33 |  |  |  |
|  |  | 2 | 0.1% II |  |  |  |  |  | 22 |  |  |  |  |  | 25 |  |  |  |
|  |  | 3 | 1% II |  |  |  |  |  | 85 |  |  |  |  |  | 47 |  |  |  |
|  |  | 4 | 1% S-II |  |  |  |  |  | 75 |  |  |  |  |  | 48 |  |  |  |
|  |  | 5 | LTW |  |  |  |  |  | 38 |  |  |  |  |  | 23 |  |  |  |
|  |  | 6 | 0.1% II |  |  |  |  |  | 28 |  |  |  |  |  | 27 |  |  |  |
|  |  | 7 | 1% II |  |  |  |  |  | 64 |  |  |  |  |  | 45 |  |  |  |
|  |  | 8 | 1% S-II |  |  |  |  |  | 93 |  |  |  |  |  | 87 |  |  |  |
| 7-18 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 22.4 | 1.75 | 0.86 |  |  |  |  | 39 | 4 |  | 3 | 25 |  |  | 7.4 |
|  |  | 2 | 0.1% II |  | 2.97 | 1.33 |  |  |  |  | 36 | 2 |  | 4 | 23 |  |  | 7.6 |
|  |  | 3 | 1% II |  | 5.65 | 3.69 |  |  |  |  | 20 | 1 |  | 12 | 23 |  |  | 8.2 |
|  |  | 4 | 1% S-II |  | 4.02 | 2.10 |  |  |  |  | 16 | <1 |  | 18 | 27 |  |  | 8.1 |
|  |  | 5 | LTW |  | 2.10 | 0.76 |  |  |  |  | 18 | 2 |  | 4 | 43 |  |  | 7.1 |
|  |  | 6 | 0.1% II |  | 2.73 | 1.29 |  |  |  |  | 14 | 1 |  | 7 | 36 |  |  | 7.8 |
|  |  | 7 | 1% II |  | 4.20 | 2.33 |  |  |  |  | <5 | <1 |  | 15 | 38 |  |  | 8.3 |
|  |  | 8 | 1% S-II |  | 5.44 | 3.18 |  |  |  |  | 10 | <1 |  | 46 | 66 |  |  | 8.4 |
| 7-21 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 23.8 | 1.99 | 1.38 |  |  |  | 12 | 64 | 7 | 83 | 3 | 26 |  | 96 | 7.6 |
|  |  | 2 | 0.1% II |  | 4.66 | 2.57 |  |  |  | 83 | 64 | 6 | 153 | 7 | 127 |  | 96 | 7.9 |
|  |  | 3 | 1% II |  | 9.79 | 5.26 |  |  |  | 27 | 98 | 7 | 126 | 17 | 45 |  | 95 | 8.5 |
|  |  | 4 | 1% S-II |  | 3.85 | 2.63 |  |  |  | 32 | 62 | 7 | 101 | 16 | 112 |  | 92 | 8.3 |
|  |  | 5 | LTW |  | 2.27 | 0.84 |  |  |  | <5 | 6 | 8 | 16 | 3 | 19 |  | 94 | 7.9 |
|  |  | 6 | 0.1% II |  | 3.39 | 2.01 |  |  |  | 58 | 46 | 10 | 114 | 9 | 23 |  | 94 | 7.9 |
|  |  | 7 | 1% II |  | 9.27 | 4.91 |  |  |  | 116 | 51 | 7 | 174 | 19 | 32 |  | 97 | 8.5 |
|  |  | 8 | 1% S-II |  | 9.87 | 4.86 |  |  |  | 121 | 52 | 7 | 180 | 22 | 38 |  | 94 | 8.3 |

TABLE D-1 (Continued)

| Date | Pond Detention Time # days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples |  |  |  |  | GF/C Filtered Samples |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Suspended Solids mg/ℓ | Volatile Suspended Solids mg/ℓ | Nitrogen as N |  | Total Phosphorus µg/ℓ | Nitrogen as N |  |  |  | Phosphorus as P |  | Fe µg/ℓ | Cond. ($10^{-6}$) mhos | pH |
|  |  |  |  |  |  |  | Organic µg/ℓ | $NH_3$ µg/ℓ |  | Organic µg/ℓ | $NH_3$ µg/ℓ | $NO_2$-$NO_3$ µg/ℓ | Total µg/ℓ | $PO_4$ µg/ℓ | Total µg/ℓ |  |  |  |
| 7-23 | 8 Assay No. 1 | 1 | LTW | 24.7 | 1.91 | 0.78 |  |  |  |  | 54 | 2 |  | 4 | 4 |  | 97 | 7.9 |
|  |  | 2 | 0.1% II |  | 3.31 | 1.12 |  |  |  |  | 50 | 10 |  | 5 | 7 |  | 97 | 8.0 |
|  |  | 3 | 1% II |  | 7.10 | 3.79 |  |  |  |  | 56 | 4 |  | 12 | 20 |  | 99 | 8.5 |
|  |  | 4 | 1% S-II |  | 3.50 | 1.75 |  |  |  |  | 36 | 3 |  | 23 | 28 |  | 96 | 8.6 |
|  |  | 5 | LTW |  | 2.14 | 0.76 |  |  |  |  | 39 | 6 |  | 5 | 13 |  | 95 | 8.1 |
|  |  | 6 | 0.1% II |  | 3.20 | 1.16 |  |  |  |  | 38 | 8 |  | 6 | 14 |  | 96 | 8.1 |
|  |  | 7 | 1% II |  | 10.46 | 5.03 |  |  |  |  | 28 | 3 |  | 8 | 26 |  | 98 | 8.5 |
|  |  | 8 | 1% S-II |  | 12.01 | 5.19 |  |  |  |  | 62 | 1 |  | 19 | 28 |  | 95 | 8.8 |
| 7-25 | 8 Assay No. 1 | 1 | LTW | 23.8 | 1.96 | 0.89 |  |  |  |  | 45 | 5 |  | 3 | 9 |  |  | 7.4 |
|  |  | 2 | 0.1% II |  | 3.85 | 1.48 |  |  |  |  | 25 | 4 |  | 3 | 10 |  |  | 7.9 |
|  |  | 3 | 1% II |  | 9.92 | 4.81 |  |  |  |  | 34 | 4 |  | 8 | 20 |  |  | 8.2 |
|  |  | 4 | 1% S-II |  | 10.89 | 5.00 |  |  |  |  | 38 | 6 |  | 17 | 24 |  |  | 8.1 |
|  |  | 5 | LTW |  | 2.59 | 0.84 |  |  |  |  | 28 | 6 |  | 3 | 11 |  |  | 8.0 |
|  |  | 6 | 0.1% II |  | 3.54 | 1.43 |  |  |  |  | 26 | 2 |  | 3 | 9 |  |  | 8.0 |
|  |  | 7 | 1.0% II |  | 10.60 | 4.96 |  |  |  |  | 10 | 6 |  | 12 | 27 |  |  | 8.4 |
|  |  | 8 | 1% S-II |  | 11.11 | 5.27 |  |  |  |  | 70 | 6 |  | 14 | 28 |  |  | 8.1 |
| 7-28 | 8 Assay No. 1 | 1 | LTW | 23.1 | 0.71 | 0.71 |  |  |  | 13 | 54 | 4 | 73 | 1 | 4 |  | 95 | 7.9 |
|  |  | 2 | 0.1% II |  | 3.03 | 1.38 |  |  |  | 38 | 20 | 1 | 59 | 3 | 7 |  | 91 | 8.0 |
|  |  | 3 | 1% II |  | 9.92 | 4.94 |  |  |  | 55 | 45 | 2 | 102 | 15 | 28 |  | 99 | 8.2 |
|  |  | 4 | 1% S-II |  | 7.55 | 4.03 |  |  |  | 44 | 20 | 3 | 67 | 22 | 31 |  | 98 | 8.2 |
|  |  | 5 | LTW |  | 2.04 | 0.82 |  |  |  | 30 | 10 | 2 | 42 | 3 | 7 |  | 92 | 8.0 |
|  |  | 6 | 0.1% II |  | 2.73 | 1.24 |  |  |  | 22 | 12 | 1 | 35 | 3 | 10 |  | 97 | 8.0 |
|  |  | 7 | 1% II |  | 10.43 | 5.08 |  |  |  | 46 | 10 | <1 | 56 | 15 | 28 |  | 100 | 8.5 |
|  |  | 8 | 1% S-II |  | 10.84 | 4.88 |  |  |  | 76 | 26 | <1 | 102 | 23 | 31 |  | 98 | 8.0 |
| 7-30 | 8 Assay No. 1 | 1 | LTW | 23.0 | 1.05 |  |  |  |  |  | 8 | 5 |  | 2 | 7 |  |  | 7.8 |
|  |  | 2 | 0.1% II |  | 2.93 |  |  |  |  |  | 8 | 5 |  | 3 | 28 |  |  | 7.9 |
|  |  | 3 | 1% II |  | 10.67 |  |  |  |  |  | 22 | 3 |  | 14 | 22 |  |  | 8.2 |
|  |  | 4 | 1% S-II |  | 8.57 |  |  |  |  |  | 10 | 3 |  | 22 | 32 |  |  | 8.2 |
|  |  | 5 | LTW |  | 2.04 |  |  |  |  |  | 4 | 5 |  | 2 | 4 |  |  | 7.9 |
|  |  | 6 | 0.1% II |  | 2.81 |  |  |  |  |  | 18 | 5 |  | 3 | 11 |  |  | 7.9 |
|  |  | 7 | 1% II |  | 11.25 |  |  |  |  |  | 36 | 4 |  | 15 | 33 |  |  | 8.2 |
|  |  | 8 | 1% S-II |  | 10.41 |  |  |  |  |  | 30 | 3 |  | 23 | 34 |  |  | 8.1 |
| 8- 1 | 8 Assay No. 1 | 1 | LTW | 24.8 | 2.11 | 0.83 |  |  |  |  | 11 | 6 |  | 3 | 8 |  |  | 8.0 |
|  |  | 2 | 0.1% II |  | 5.50 | 1.87 |  |  |  |  | 8 | 7 |  | 4 | 20 |  |  | 8.1 |
|  |  | 3 | 1% II |  | 12.11 | 5.28 |  |  |  |  | [illegible] | 8 |  | 18 | 31 |  |  | 8.4 |
|  |  | 4 | 1% S-II |  | 12.22 | 5.46 |  |  |  |  | 14 | 6 |  | 23 | 33 |  |  | 8.4 |
|  |  | 5 | LTW |  | 2.85 | 0.90 |  |  |  |  | 14 | 7 |  | 2 | 5 |  |  | 8.0 |
|  |  | 6 | 0.1% II |  |  |  |  |  |  |  | 38 | 6 |  | 4 | 16 |  |  | 8.1 |
|  |  | 7 | 1% II |  | 11.97 | 5.43 |  |  |  |  | 30 | 8 |  | 19 | 32 |  |  | 8.3 |
|  |  | 8 | 1% S-II |  | 12.41 | 4.83 |  |  |  |  | 14 | 5 |  | 23 | 30 |  |  | 8.3 |

TABLE D-1 (Continued)

| Date | Pond Detention Time # days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples: Suspended Solids mg/ℓ | Unfiltered Samples: Volatile Suspended Solids mg/ℓ | Unfiltered Samples: Nitrogen as N: Organic µg/ℓ | Unfiltered Samples: Nitrogen as N: $NH_3$ µg/ℓ | Unfiltered Samples: Total Phosphorus µg/ℓ | GF/C Filtered Samples: Nitrogen as N: Organic µg/ℓ | GF/C Filtered Samples: Nitrogen as N: $NH_3$ µg/ℓ | GF/C Filtered Samples: Nitrogen as N: $NO_2$-$NO_3$ µg/ℓ | GF/C Filtered Samples: Nitrogen as N: Total µg/ℓ | GF/C Filtered Samples: Phosphorus as P: $PO_4$ µg/ℓ | GF/C Filtered Samples: Phosphorus as P: Total µg/ℓ | Fe µg/ℓ | Cond. $(10^{-6})$ mhos | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-4 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 22.6 | 1.80 | 0.82 | | | | 32 | 4 | 3 | 39 | 2 | 5 | | 90 | 7.8 |
| | | 2 | 0.1% II | | 3.74 | 1.27 | | | | 35 | 20 | 2 | 57 | 4 | 11 | | 92 | 7.9 |
| | | 3 | 1% II | | 12.75 | 5.51 | | | | 62 | 9 | 2 | 73 | 13 | 20 | | 94 | 8.6 |
| | | 4 | 1% S-II | | 10.51 | 4.66 | | | | 71 | 30 | 2 | 103 | 19 | 25 | | 93 | 8.2 |
| | | 5 | LTW | | 1.91 | 0.68 | | | | 23 | 15 | 2 | 40 | 2 | 4 | | 89 | 8.1 |
| | | 6 | 0.1% II | | 2.68 | 1.10 | | | | 27 | 9 | 2 | 38 | 4 | 9 | | 91 | 8.1 |
| | | 7 | 1% II | | 11.50 | 5.04 | | | | 67 | 15 | 2 | 84 | 15 | 22 | | 94 | 8.7 |
| | | 8 | 1% S-II | | 12.74 | 5.15 | | | | 36 | 9 | 1 | 46 | 16 | 22 | | 93 | 8.5 |
| 8-5 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 21.8 | 2.26 | 1.00 | | | | | | | | | | | | |
| | | 2 | 0.1% II | | 4.52 | 1.55 | | | | | | | | | | | | |
| | | 3 | 1% II | | 12.54 | 5.37 | | | | | | | | | | | | |
| | | 4 | 1% S-II | | 12.34 | 5.21 | | | | | | | | | | | | |
| | | 5 | LTW | | 2.50 | 0.84 | | | | | | | | | | | | |
| | | 6 | 0.1% II | | 3.56 | 1.48 | | | | | | | | | | | | |
| | | 7 | 1% II | | 12.39 | 5.20 | | | | | | | | | | | | |
| | | 8 | 1% S-II | | 13.21 | 5.36 | | | | | | | | | | | | |
| 8-6 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 21.4 | 2.55 | 1.07 | | | | | 24 | 7 | | 4 | 24 | 8 | | 7.9 |
| | | 2 | 0.1% II | | 4.42 | 1.70 | | | | | 24 | 6 | | 7 | 34 | <1 | | 7.9 |
| | | 3 | 1% II | | 14.25 | 6.34 | | | | | 18 | 6 | | 11 | 32 | <1 | | 8.3 |
| | | 4 | 1% S-II | | 12.61 | 5.65 | | | | | 22 | 6 | | 19 | 63 | <1 | | 8.2 |
| | | 5 | LTW | | 2.28 | 0.82 | | | | | 9 | 6 | | 3 | 14 | <1 | | 8.0 |
| | | 6 | 0.1% II | | 3.56 | 1.41 | | | | | 20 | 7 | | 6 | 39 | 2 | | 8.0 |
| | | 7 | 1% II | | 13.52 | 5.87 | | | | | 6 | 8 | | 18 | 38 | <1 | | 8.3 |
| | | 8 | 1% S-II | | 14.56 | 6.27 | | | | | 18 | 7 | | 13 | 41 | <1 | | 8.4 |
| 8-7 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 21.1 | 2.53 | | | | | | | | | | | | | |
| | | 2 | 0.1% II | | 4.07 | | | | | | | | | | | | | |
| | | 3 | 1% II | | 13.72 | | | | | | | | | | | | | |
| | | 4 | 1% S-II | | 12.43 | | | | | | | | | | | | | |
| | | 5 | LTW | | 1.73 | | | | | | | | | | | | | |
| | | 6 | 0.1% II | | 3.16 | | | | | | | | | | | | | |
| | | 7 | 1% II | | 12.94 | | | | | | | | | | | | | |
| | | 8 | 1% S-II | | 16.39 | | | | | | | | | | | | | |
| 8-8 | 8<br>Assay<br>No.<br>1 | 1 | LTW | 21.6 | 0.75 | 0.75 | 91 | 40 | 23 | 70 | 39 | 11 | 120 | 2 | 23 | | 95 | 7.9 |
| | | 2 | 0.1% II | | 2.88 | 1.21 | 89 | 40 | 35 | 92 | 24 | 10 | 126 | 4 | 31 | | 92 | 8.0 |
| | | 3 | 1% II | | 12.59 | 5.24 | 249 | 35 | 101 | 87 | 35 | 10 | 132 | 12 | 35 | | 92 | 8.2 |
| | | 4 | 1% S-II | | 11.24 | 4.18 | 170 | 26 | 116 | 86 | 21 | 10 | 117 | 18 | 42 | | 94 | 8.1 |
| | | 5 | LTW | | 2.33 | 0.63 | 62 | 32 | 22 | 57 | 44 | 10 | 111 | 2 | 20 | | 94 | 8.0 |
| | | 6 | 0.1% II | | 3.52 | 1.21 | 70 | 31 | 33 | 75 | 42 | 10 | 127 | 4 | 23 | | 91 | 8.0 |
| | | 7 | 1% II | | 11.87 | 4.60 | 154 | 29 | 110 | 106 | 28 | 9 | 143 | 10 | 22 | | 94 | 8.4 |
| | | 8 | 1% S-II | | 14.69 | 5.43 | 198 | 40 | 107 | 111 | 44 | 10 | 165 | 10 | 70 | | [illegible] | 8.4 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples | | | | | GF/C Filtered Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suspended Solids mg/l | Volatile Suspended Solids mg/l | Nitrogen as N Organic μg/l | Nitrogen as N $NH_3$ μg/l | Total Phosphorus μg/l | Nitrogen as N Organic μg/l | Nitrogen as N $NH_3$ μg/l | Nitrogen as N $NO_2$-$NO_3$ μg/l | Nitrogen as N Total μg/l | Phosphorus as P $PO_4$ μg/l | Phosphorus as P Total μg/l | Fe μg/l | Cond. ($10^{-6}$) mhos | pH |
| 8-11 | 5 Assay No. 2 | 1 | LTW | 23.2 | 1.66 | 0.70 | | | | 99 | 35 | 3 | 138 | 4 | 64 | 18 | 96 | 7.7 |
| | | 2 | 0.1% II | | 3.80 | 1.27 | | | | 120 | 32 | 4 | 156 | 7 | 28 | 2 | 94 | 7.8 |
| | | 3 | 1% II | | 12.52 | 5.44 | | | | 113 | 24 | <1 | 138 | 28 | 70 | <1 | 96 | 8.3 |
| | | 4 | 1% S-II | | 13.43 | 5.69 | | | | 123 | 38 | 4 | 165 | 27 | 52 | <1 | 94 | 8.3 |
| | | 5 | LTW | | 1.83 | 0.56 | | | | 81 | 45 | 2 | 128 | 5 | 29 | 11 | 95 | 7.7 |
| | | 6 | 0.1% II | | 2.67 | 0.91 | | | | 80 | 63 | 2 | 145 | 5 | 44 | <1 | 96 | 7.8 |
| | | 7 | 1% II | | 13.56 | 5.64 | | | | 138 | 55 | 4 | 197 | 27 | 62 | <1 | 92 | 8.2 |
| | | 8 | 1% S-II | | 13.75 | 5.75 | | | | 149 | 39 | 2 | 140 | 17 | 48 | <1 | 92 | - |
| 8-13 | 5 Assay No. 2 | 1 | LTW | 22.2 | 1.69 | | | | | | 34 | 11 | | 2 | 5 | | | 8.0 |
| | | 2 | 0.1% II | | 3.63 | | | | | | 45 | 11 | | 7 | 7 | | | 8.1 |
| | | 3 | 1% II | | 12.38 | | | | | | 47 | 10 | | 31 | 38 | | | 8.5 |
| | | 4 | 1% S-II | | 15.68 | | | | | | 33 | 10 | | 30 | 32 | | | 8.8 |
| | | 5 | LTW | | 2.30 | | | | | | 30 | 10 | | 3 | 6 | | | 8.2 |
| | | 6 | 0.1% II | | 2.99 | | | | | | 20 | 11 | | 8 | 10 | | | 8.1 |
| | | 7 | 1% II | | 12.96 | | | | | | 22 | 11 | | 34 | 38 | | | 8.5 |
| | | 8 | 1% S-II | | 13.69 | | | | | | 25 | 10 | | 17 | 22 | | | 8.5 |
| 8-15 | 5 Assay No. 2 | 1 | LTW | 23.1 | 2.25 | 0.77 | | | | | 42 | 9 | | 1 | 6 | | | 8.1 |
| | | 2 | 0.1% II | | 2.72 | 1.10 | | | | | 40 | 5 | | 6 | 10 | | | 8.2 |
| | | 3 | 1% II | | 11.84 | 6.05 | | | | | 50 | 6 | | 34 | 41 | | | 8.6 |
| | | 4 | 1% S-II | | 13.61 | 6.45 | | | | | 59 | 4 | | 18 | 23 | | | 8.0 |
| | | 5 | LTW | | 2.20 | 0.69 | | | | | 39 | 6 | | 2 | 3 | | | 8.2 |
| | | 6 | 0.1% II | | 2.95 | 1.22 | | | | | 84 | 10 | | 7 | 11 | | | 8.2 |
| | | 7 | 1% II | | 12.82 | 7.57 | | | | | 87 | 7 | | 26 | 36 | | | 8.7 |
| | | 8 | 1% S-II | | 14.74 | 6.74 | | | | | 63 | 5 | | 18 | 19 | | | 8.8 |
| 8-18 | 5 Assay No. 2 | 1 | LTW | 22.5 | 1.71 | 0.62 | | | | 69 | 46 | 17 | 132 | 4 | 58 | | 91 | 8.1 |
| | | 2 | 0.1% II | | 3.06 | 1.00 | | | | 96 | 39 | 17 | 152 | 9 | 56 | | 88 | 8.1 |
| | | 3 | 1% II | | 8.48 | 5.04 | | | | 101 | 48 | 17 | 166 | 22 | 93 | | 90 | 8.4 |
| | | 4 | 1% S-II | | 14.73 | 5.64 | | | | 98 | 31 | 18 | 147 | 18 | 72 | | 88 | 8.5 |
| | | 5 | LTW | | 2.21 | 0.58 | | | | 75 | 54 | 19 | 148 | 4 | 47 | | 69 | 8.1 |
| | | 6 | 0.1% II | | 2.38 | 0.83 | | | | | 39 | 20 | | 8 | 58 | | 88 | 8.1 |
| | | 7 | 1% II | | 11.89 | 6.28 | | | | 88 | 51 | 17 | 156 | 16 | 35 | | 94 | 8.6 |
| | | 8 | 1% S-II | | 13.79 | 6.15 | | | | | 30 | 19 | | 16 | 50 | | 92 | 8.0 |
| 8-19 | 5 Assay No. 2 | 1 | LTW | 22.0 | 2.74 | 0.81 | | | | | | | | | | | | |
| | | 2 | 0.1% II | | 4.58 | 1.38 | | | | | | | | | | | | |
| | | 3 | 1% II | | 11.43 | 7.00 | | | | | | | | | | | | |
| | | 4 | 1% S-II | | 15.00 | 7.03 | | | | | | | | | | | | |
| | | 5 | LTW | | 2.52 | 0.75 | | | | | | | | | | | | |
| | | 6 | 0.1% II | | 2.78 | 1.05 | | | | | | | | | | | | |
| | | 7 | 1% II | | 11.66 | 6.69 | | | | | | | | | | | | |
| | | 8 | 1% S-II | | 13.75 | 6.36 | | | | | | | | | | | | 8.6 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples |  |  |  |  | GF/C Filtered Samples |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Suspended Solids mg/l | Volatile Suspended Solids mg/l | Nitrogen as N |  | Total Phosphorus µg/l | Nitrogen as N |  |  |  | Phosphorus as P |  | Fe µg/l | Cond. ($10^{-6}$) mhos | pH |
|  |  |  |  |  |  |  | Organic µg/l | $NH_3$ µg/l |  | Organic µg/l | $NH_3$ µg/l | $NO_2$-$NO_3$ µg/l | Total µg/l | $PO_4$ µg/l | Total µg/l |  |  |  |
| 8-20 | 5 Assay No. 2 | 1 | LTW | 22.2 | 1.56 | 0.81 |  |  |  |  | 31 | 6 |  | 3 | 15 | <1 |  | 8.0 |
|  |  | 2 | 0.1% II |  | 3.04 | 1.58 |  |  |  |  | 33 | 6 |  | 13 | 19 | <1 |  | 8.1 |
|  |  | 3 | 1% II |  | 11.88 | 7.23 |  |  |  |  | 37 | 5 |  | 16 | 19 | <1 |  | 8.4 |
|  |  | 4 | 1% S-II |  | 12.40 | 3.96 |  |  |  |  | 37 | 4 |  | 21 | 31 | <1 |  | 8.7 |
|  |  | 5 | LTW |  | 1.61 | 0.90 |  |  |  |  | 37 | 5 |  | 2 | 5 | <1 |  | 8.0 |
|  |  | 6 | 0.1% II |  | 2.79 | 1.26 |  |  |  |  | 29 | 5 |  | 6 | 8 | <1 |  | 8.2 |
|  |  | 7 | 1% II |  | 11.03 | 6.88 |  |  |  |  | 30 | 4 |  | 7 | 61 | <1 |  | 8.4 |
|  |  | 8 | 1% S-II |  | 13.74 | 7.49 |  |  |  |  | 18 | 6 |  | 15 | 17 | <1 |  | 8.7 |
| 8-21 | 5 Assay No. 2 | 1 | LTW | 22.8 | 1.85 |  |  |  |  |  |  |  |  |  |  |  |  | 8.1 |
|  |  | 2 | 0.1% II |  | 3.15 |  |  |  |  |  |  |  |  |  |  |  |  | 8.0 |
|  |  | 3 | 1% II |  | 12.98 |  |  |  |  |  |  |  |  |  |  |  |  | 8.6 |
|  |  | 4 | 1% S-II |  | 14.87 |  |  |  |  |  |  |  |  |  |  |  |  | 8.2 |
|  |  | 5 | LTW |  | 1.93 |  |  |  |  |  |  |  |  |  |  |  |  | 8.0 |
|  |  | 6 | 0.1% II |  | 2.94 |  |  |  |  |  |  |  |  |  |  |  |  | 8.0 |
|  |  | 7 | 1% II |  | 11.88 |  |  |  |  |  |  |  |  |  |  |  |  | 8.7 |
|  |  | 8 | 1% S-II |  | 13.42 |  |  |  |  |  |  |  |  |  |  |  |  | 8.1 |
| 8-22 | 5 Assay No. 2 | 1 | LTW | 22.7 | 2.09 | 0.93 | 144 | 31 | 6 | 160 | 32 | 6 | 198 | 6 | 6 |  | 91 | 8.1 |
|  |  | 2 | 0.1% II |  | 3.92 | 1.42 | 147 | 16 | 18 | 185 | 38 | 5 | 228 | 9 | 10 |  | 91 | 8.1 |
|  |  | 3 | 1% II |  | 12.19 | 7.04 | 250 | 33 | 102 | 114 | 35 | 4 | 153 | 11 | 16 |  | 91 | 8.2 |
|  |  | 4 | 1% S-II |  | 13.40 | 5.20 | 178 | 37 | 105 | 94 | 45 | 4 | 193 | 32 | 34 |  | 93 | 8.1 |
|  |  | 5 | LTW |  | 2.73 | 0.78 | 38 | 14 | 11 | 99 | 36 | 5 | 140 | 4 | 5 |  | 90 | 8.1 |
|  |  | 6 | 0.1% II |  | 3.35 | 1.27 | 107 | 12 | 16 | 61 | 40 | 5 | 106 | 7 | 8 |  | 93 | 8.2 |
|  |  | 7 | 1% II |  | 10.94 | 7.23 | 226 | 8 | 103 | 148 | 32 | 6 | 186 | 6 | 9 |  | 93 | 8.2 |
|  |  | 8 | 1% S-II |  | 14.50 | 6.50 | 198 | 6 | 121 | 106 | 20 | 3 | 129 | 12 | 14 |  | 92 | 8.3 |
| 8-25 | 3 Assay No. 3 | 1 | LTW | 20.8 | 1.77 | 0.63 |  |  |  | 48 | 48 | 13 | 109 | 4 | 4 | 2 | 91 | 8.0 |
|  |  | 2 | 0.1% II |  | 2.50 | 0.82 |  |  |  | 116 | 52 | 10 | 178 | 6 | 20 | <1 | 90 | 8.0 |
|  |  | 3 | 1% II |  | 7.98 | 4.45 |  |  |  | 114 | 100 | 7 | 221 | 22 | 31 | <1 | 90 | 8.5 |
|  |  | 4 | 1% S-II |  | 8.48 | 3.48 |  |  |  | 122 | 49 | 7 | 178 | 40 | 45 | <1 | 92 | 8.4 |
|  |  | 5 | LTW |  | 1.93 | 0.62 |  |  |  | 90 | 42 | 11 | 143 | 3 | 8 |  | 93 | 8.0 |
|  |  | 6 | 0.1% II |  | 2.66 | 1.10 |  |  |  | 95 | 54 | 6 | 155 | 4 | 53 |  | 93 | 8.1 |
|  |  | 7 | 1% II |  | 9.33 | 6.02 |  |  |  | 96 | 70 | 7 | 173 | 10 | 19 | 1 | 97 | 8.8 |
|  |  | 8 | 1% S-II |  | 11.78 | 5.17 |  |  |  | 98 | 44 | 5 | 147 | 23 | 28 | <1 | 96 | 8.7 |
| 8-27 | 3 Assay No. 3 | 1 | LTW | 19.2 | 1.80 |  |  |  |  |  | 24 | 13 |  | 4 | 7 |  |  |  |
|  |  | 2 | 0.1% II |  | 2.29 |  |  |  |  |  | 31 | 16 |  | 6 | 12 |  |  |  |
|  |  | 3 | 1% II |  | 6.50 |  |  |  |  |  | 30 | 12 |  | 24 | 30 |  |  | 8.5 |
|  |  | 4 | 1% S-II |  | 7.20 |  |  |  |  |  | 40 | 8 |  | 30 | 37 |  |  | 8.5 |
|  |  | 5 | LTW |  | 1.97 |  |  |  |  |  | 33 | 15 |  | 4 | 7 |  |  |  |
|  |  | 6 | 0.1% II |  | 2.71 |  |  |  |  |  | 35 | 13 |  | 6 | 9 |  |  |  |
|  |  | 7 | 1% II |  | 8.42 |  |  |  |  |  | 31 | 11 |  | 17 | 20 |  |  | 8.4 |
|  |  | 8 | 1% S-II |  | 10.21 |  |  |  |  |  | 36 | 7 |  | 23 | 24 |  |  | 8.4 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples | | | | | GF/C Filtered Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suspended Solids | Volatile Suspended Solids | Nitrogen as N | | Total Phosphorus | Nitrogen as N | | | | Phosphorus as P | | Fe | Cond. $(10^{-6})$ | pH |
| | | | | | mg/ℓ | mg/ℓ | Organic µg/ℓ | NH$_3$ µg/ℓ | µg/ℓ | Organic µg/ℓ | NH$_3$ µg/ℓ | NO$_2$-NO$_3$ µg/ℓ | Total µg/ℓ | PO$_4$ µg/ℓ | Total µg/ℓ | µg/ℓ | mhos | |
| 8-29 | 3 Assay No. 3 | 1 | LTW | 18.8 | 1.24 | 0.62 | | | | | 12 | 16 | | 4 | 13 | | | 8.1 |
| | | 2 | 0.1% II | | 1.80 | 0.78 | | | | | 21 | 15 | | 7 | 20 | | | 8.2 |
| | | 3 | 1% II | | 7.50 | 4.33 | | | | | 9 | 11 | | 28 | 51 | | | 8.7 |
| | | 4 | 1% S-II | | 4.39 | 2.87 | | | | | 27 | 8 | | 21 | 32 | | | 8.3 |
| | | 5 | LTW | | 1.96 | 0.68 | | | | | 14 | 13 | | 2 | 30 | | | 8.0 |
| | | 6 | 0.1% II | | 2.05 | 2.05 | | | | | 28 | 13 | | 9 | 18 | | | 8.0 |
| | | 7 | 1% II | | 8.37 | 5.83 | | | | | 34 | 7 | | 16 | 37 | | | 8.5 |
| | | 8 | 1% S-II | | 13.53 | 3.87 | | | | | 32 | 8 | | 26 | 43 | | | 8.7 |
| 9- 1 | 3 Assay No. 3 | 1 | LTW | 20.8 | 1.49 | 0.67 | | | | 48 | 30 | 13 | 91 | 4 | 9 | 10 | 86 | 8.1 |
| | | 2 | 0.1% II | | 2.12 | 0.91 | | | | 86 | 20 | 14 | 120 | 8 | 10 | <1 | 87 | 8.1 |
| | | 3 | 1% II | | 7.82 | 4.96 | | | | 107 | 38 | 13 | 158 | 22 | 25 | <1 | 91 | 8.3 |
| | | 4 | 1% S-II | | 4.89 | 3.38 | | | | 95 | 40 | 16 | 151 | 14 | 16 | <1 | | 8.4 |
| | | 5 | LTW | | 1.70 | 0.53 | | | | 46 | 20 | 12 | 78 | 8 | 8 | 2 | 87 | 8.0 |
| | | 6 | 0.1% II | | 2.75 | 1.12 | | | | | 54 | 14 | | 6 | 7 | <1 | 88 | 7.9 |
| | | 7 | 1% II | | 7.95 | 5.68 | | | | 90 | 29 | 16 | 135 | 31 | 32 | <1 | | 8.6 |
| | | 8 | 1% S-II | | 7.48 | 4.04 | | | | 60 | 42 | 13 | 115 | 20 | 23 | <1 | | 8.7 |
| 9- 2 | 3 Assay No. 3 | 1 | LTW | 21.2 | 1.36 | | | | | | | | | | | | | |
| | | 2 | 0.1% II | | 2.14 | | | | | | | | | | | | | |
| | | 3 | 1% II | | 7.57 | | | | | | | | | | | | | |
| | | 4 | 1% S-II | | 4.49 | | | | | | | | | | | | | |
| | | 5 | LTW | | 1.13 | | | | | | | | | | | | | |
| | | 6 | 0.1% II | | 2.29 | | | | | | | | | | | | | |
| | | 7 | 1% II | | 8.10 | | | | | | | | | | | | | |
| | | 8 | 1% S-II | | 8.16 | | | | | | | | | | | | | |
| 9- 3 | 3 Assay No. 3 | 1 | LTW | 21.0 | 1.51 | 0.70 | 77 | 24 | 10 | 60 | 10 | 4 | 72 | 2 | 8 | | 90 | 7.9 |
| | | 2 | 0.1% II | | 2.60 | 1.13 | 72 | 14 | 18 | 62 | 24 | 6 | 92 | 5 | 10 | | 91 | 8.0 |
| | | 3 | 1% II | | 8.03 | 4.85 | 156 | 16 | 92 | 65 | 18 | 4 | 87 | 32 | 38 | | 90 | 8.8 |
| | | 4 | 1% S-II | | 5.15 | 3.18 | 170 | 8 | 69 | 58 | 18 | 3 | 79 | 13 | 23 | | 92 | 8.7 |
| | | 5 | LTW | | 1.45 | 0.49 | 58 | 12 | 8 | 41 | 13 | 6 | 60 | 2 | 7 | | 88 | 7.9 |
| | | 6 | 0.1% II | | 2.93 | 1.18 | 50 | 12 | 15 | 50 | 25 | 4 | 79 | 4 | 10 | | 89 | 7.9 |
| | | 7 | 1% II | | 6.57 | 4.90 | 156 | 22 | 85 | 91 | 23 | 3 | 117 | 33 | 39 | | 92 | 8.7 |
| | | 8 | 1% S-II | | 9.22 | 4.76 | 134 | 10 | 77 | 82 | 22 | 2 | 106 | 9 | 16 | | 90 | 8.7 |
| 9- 8 | 8 Assay No. 4 | 1 | LTW[b] | 20.3 | | | 65 | 67 | 21 | 40 | 63 | 11 | 114 | 6 | 11 | | 88 | 7.9 |
| | | 2 | 2% III | | | | 65 | 182 | 19 | 62 | 315 | 13 | 390 | 6 | 11 | | 96 | 7.9 |
| | | 3 | 1% III | | | | 50 | 328 | 12 | 12 | 171 | 10 | 193 | 4 | 9 | | 92 | 7.9 |
| | | 4 | 1% III + TE | | | | 131 | 861 | 11 | 34 | 161 | 11 | 206 | 3 | 6 | | 92 | 7.9 |
| | | 5 | LTW | | | | 122 | 82 | 9 | <5 | 83 | 11 | 96 | 5 | 7 | | 88 | 7.9 |
| | | 6 | 2% III | | | | 88 | 282 | 12 | 22 | 300 | 13 | 335 | 5 | 11 | | 97 | 8.0 |
| | | 7 | 1% III | | | | 84 | 148 | 15 | 50 | 162 | 11 | 223 | 5 | 8 | | 91 | 8.0 |
| | | 8 | 1% III + TE | | | | 85 | 139 | 21 | 91 | 177 | 8 | 276 | 5 | 7 | | 91 | 8.0 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Sample |  |  |  |  | GF/C Filtered Sample |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Suspended Solids | Volatile Suspended Solids | Nitrogen as N |  | Total Phosphorus | Nitrogen as N |  |  |  | Phosphorus as P |  | Fe | Cond. ($10^{-6}$) | pH |
|  |  |  |  |  | mg/ℓ | mg/ℓ | Organic μg/ℓ | $NH_3$ μg/ℓ | μg/ℓ | Organic μg/ℓ | $NH_3$ μg/ℓ | $NO_2$-$NO_3$ μg/ℓ | Total μg/ℓ | $PO_4$ μg/ℓ | Total μg/ℓ | μg/ℓ | mhos |  |
| 9-10 | 8<br>Assay<br>No.<br>4 | 1 | LTW | 19.9 | 0.39 | 0.34 |  |  |  |  | 31 | 10 |  | 2 | 5 |  | 90 | 8.1 |
|  |  | 2 | 2% III |  | 0.38 | 0.32 |  |  |  |  | 280 | 18 |  | 3 | 6 |  | 94 | 7.9 |
|  |  | 3 | 1% III |  | 0.33 | 0.30 |  |  |  |  | 134 | 16 |  | 4 | 6 |  | 90 | 7.9 |
|  |  | 4 | 1% III + TE |  | 0.34 | 0.28 |  |  |  |  | 206 | 14 |  | 3 | 6 |  | 91 | 8.0 |
|  |  | 5 | LTW |  | 0.38 | 0.31 |  |  |  |  | 45 | 8 |  | 3 | 4 |  | 86 | 7.9 |
|  |  | 6 | 2% III |  | 0.29 | 0.23 |  |  |  |  | 289 | 16 |  | 4 | 6 |  | 94 | 8.0 |
|  |  | 7 | 1% III |  | 0.23 | 0.21 |  |  |  |  | 160 | 16 |  | 5 | 5 |  | 91 | 8.0 |
|  |  | 8 | 1% III + TE |  | 0.23 | 0.21 |  |  |  |  | 139 | 15 |  | 2 | 5 |  | 91 | 8.0 |
| 9-12 | 8<br>Assay<br>No.<br>4 | 1 | LTW | 20.1 | 0.35 | 0.26 |  |  |  |  | 14 | 10 |  | 4 |  |  |  | 7.9 |
|  |  | 2 | 2% III |  | 0.23 | 0.30 |  |  |  |  | 261 | 18 |  | 3 |  |  |  | 7.9 |
|  |  | 3 | 1% III |  | 0.39 | 0.33 |  |  |  |  | 124 | 17 |  | 2 |  |  |  | 7.9 |
|  |  | 4 | 1% III + TE |  | 0.41 | 0.39 |  |  |  |  | 110 | 17 |  | 4 |  |  |  | 7.9 |
|  |  | 5 | LTW |  | 0.39 | 0.34 |  |  |  |  | 20 | 12 |  | 2 |  |  |  | 7.8 |
|  |  | 6 | 2% III |  | 0.33 | 0.31 |  |  |  |  | 282 | 21 |  | 4 |  |  |  | 7.9 |
|  |  | 7 | 1% III |  | 0.29 | 0.26 |  |  |  |  | 122 | 18 |  | 5 |  |  |  | 8.0 |
|  |  | 8 | 1% III + TE |  | 0.41 | 0.35 |  |  |  |  | 117 | 17 |  | 3 |  |  |  | 8.0 |
| 9-15 | 8<br>Assay<br>No.<br>4 | 1 | LTW | 17.6 | 1.19 |  |  |  |  | 62 | 72 | <1 | 132 | 2 | 5 | 4 |  |  |
|  |  | 2 | 2% III |  | 1.61 |  |  |  |  | 46 | 194 | 14 | 254 | 3 | 13 | 2 |  |  |
|  |  | 3 | 1% III |  | 1.40 |  |  |  |  | 71 | 134 | 10 | 215 | 3 | 6 | 6 |  |  |
|  |  | 4 | 1% III + TE |  | 1.52 |  |  |  |  | 43 | 62 | 13 | 118 | 2 | 5 | 14 |  |  |
|  |  | 5 | LTW |  | 0.77 |  |  |  |  | 58 | 60 | 1 | 119 | 2 | 7 | <1 |  |  |
|  |  | 6 | 2% III |  | 0.79 |  |  |  |  | 34 | 229 | 20 | 283 | 3 | 6 | 2 |  |  |
|  |  | 7 | 1% III |  | 0.61 |  |  |  |  | 65 | 99 | 10 | 174 | 3 | 5 | <1 |  |  |
|  |  | 8 | 1% III + TE |  | 0.90 |  |  |  |  | 55 | 100 | 10 | 165 | 4 | 4 | 6 |  |  |
| 9-17 | 8<br>Assay<br>No.<br>4 | 1 | LTW | 16.9 | 1.28 |  |  |  |  |  | 10 | 12 |  | 3 | 6 |  |  | 7.5 |
|  |  | 2 | 2% III |  | 1.10 |  |  |  |  |  | 208 | 25 |  | 3 | 24 |  |  | 7.9 |
|  |  | 3 | 1% III |  | 1.48 |  |  |  |  |  | 96 | 10 |  | 3 | 4 |  |  | 8.1 |
|  |  | 4 | 1% III + TE |  | 1.46 |  |  |  |  |  | 88 | 23 |  | 2 | 4 |  |  | 7.2 |
|  |  | 5 | LTW |  | 0.54 |  |  |  |  |  | 26 | 11 |  | 2 | 12 |  |  | 7.8 |
|  |  | 6 | 2% III |  | 1.37 |  |  |  |  |  | 263 | 26 |  | 2 | 18 |  |  | 7.8 |
|  |  | 7 | 1% III |  | 0.86 |  |  |  |  |  | 64 | 15 |  | 2 | 23 |  |  | 7.2 |
|  |  | 8 | 1% III + TE |  | 0.30 |  |  |  |  |  | 115 | 19 |  | 1 | 5 |  |  | 7.5 |
| 9-19 | 8<br>Assay<br>No.<br>4 | 1 | LTW | 17.0 | 1.77 | 0.63 |  |  |  |  | <5 | 10 |  | 4 |  |  |  | 7.6 |
|  |  | 2 | 2% III |  | 1.75 | 0.80 |  |  |  |  | 192 | 24 |  | 4 |  |  |  | 7.9 |
|  |  | 3 | 1% III |  | 2.28 | 0.85 |  |  |  |  | 80 | 12 |  | 4 |  |  |  | 8.0 |
|  |  | 4 | 1% III + TE |  | 1.30 | 0.48 |  |  |  |  | 80 | 19 |  | 5 |  |  |  | 7.7 |
|  |  | 5 | LTW |  | 1.37 | 0.44 |  |  |  |  | <5 | 6 |  | 5 |  |  |  | 7.7 |
|  |  | 6 | 2% III |  | 1.35 | 0.74 |  |  |  |  | 239 | 23 |  | 5 |  |  |  | 7.7 |
|  |  | 7 | 1% III |  | 1.88 | 0.69 |  |  |  |  | 44 | 8 |  | 4 |  |  |  | 7.8$^{c}$ |
|  |  | 8 | 1% III + TE |  | 1.46 | 1.03 |  |  |  |  | 86 | 23 |  | 4 |  |  |  | 7.6 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples |  |  |  |  | GF/C Filtered Sample |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Suspended Solids | Volatile Suspended Solids | Nitrogen as N |  | Total Phosphorus | Nitrogen as N |  |  |  | Phosphorus as P |  | Fe | Cond. ($10^{-6}$) | pH |
|  |  |  |  |  | mg/ℓ | mg/ℓ | Organic µg/ℓ | $NH_3$ µg/ℓ | µg/ℓ | Organic µg/ℓ | $NH_3$ µg/ℓ | $NO_2$-$NO_3$ µg/ℓ | Total µg/ℓ | $PO_4$ µg/ℓ | Total µg/ℓ | µg/ℓ | mhos |  |
| 9-22 | 8<br>Assay No. 4 | 1 | LTW | 15.2 | 1.86 | 0.75 |  |  |  | 108 | 29 | 3 | 140 | 10 | 10 |  | 85 | 7.8 |
|  |  | 2 | 2% III |  | 1.98 | 1.00 |  |  |  | 62 | 212 | 33 | 307 | 4 | 4 |  | 86 | 7.7 |
|  |  | 3 | 1% III |  | 2.03 | 0.86 |  |  |  | 65 | 114 | 12 | 191 | 3 | 8 |  | 86 | 8.1 |
|  |  | 4 | 1% III + TE |  | 0.64 | 0.64 |  |  |  | 50 | 93 | 23 | 166 | 3 | 6 |  | 84 | 8.1 |
|  |  | 5 | LTW |  | 1.02 | 0.43 |  |  |  | 103 | 25 | 4 | 132 | 5 | 8 |  | 82 | 8.0 |
|  |  | 6 | 2% III |  | 1.21 | 0.77 |  |  |  |  | 212 | 26 |  | 3 | 4 |  | 87 | 8.0 |
|  |  | 7 | 1% III |  | 0.77 | 0.45 |  |  |  | 46 | 79 | 11 | 136 | 3 | 8 |  | 83 | 8.1 |
|  |  | 8 | 1% III + TE |  | 1.41 | 0.65 |  |  |  | 46 | 90 | 22 | 158 | 5 | 6 |  | 84 | 8.1 |
| 9-24 | 8<br>Assay No. 4 | 1 | LTW | 17.6 | 1.33 | 0.69 |  |  |  |  | 4 | 7 |  | 5 | 7 |  |  | 8.0 |
|  |  | 2 | 2% III |  | 1.97 | 1.10 |  |  |  |  | 189 | 38 |  | 3 | 9 |  |  | 8.1 |
|  |  | 3 | 1% III |  | 2.05 | 1.00 |  |  |  |  | 76 | 22 |  | 2 | 6 |  |  | 8.0 |
|  |  | 4 | 1% III + TE |  | 1.78 | 0.93 |  |  |  |  | 72 | 29 |  | 2 | 4 |  |  | 8.1 |
|  |  | 5 | LTW |  | 0.62 | 0.38 |  |  |  |  | 23 | 5 |  | 3 | 9 |  |  | 7.7 |
|  |  | 6 | 2% III |  | 1.09 | 0.78 |  |  |  |  | 204 | 39 |  | 3 |  |  |  | 8.2 |
|  |  | 7 | 1% III |  | 0.81 | 0.30 |  |  |  |  | 80 | 11 |  | 4 | 10 |  |  | 8.3 |
|  |  | 8 | 1% III + TE |  | 1.30 | 0.88 |  |  |  |  | 72 | 27 |  | 3 | 8 |  |  | 8.1 |
| 9-26 | 8<br>Assay No. 4 | 1 | LTW | 17.0 | 2.40 | 0.88 |  |  |  |  | 10 | 9 |  | 4 | 6 |  |  | 8.0 |
|  |  | 2 | 2% III |  | 2.82 | 1.24 |  |  |  |  | 188 | 162 |  | 3 | 5 |  |  | 8.2 |
|  |  | 3 | 1% III |  | 3.04 | 1.29 |  |  |  |  | 86 | 21 |  | 4 | 4 |  |  | 8.1 |
|  |  | 4 | 1% III + TE |  | 2.73 | 1.29 |  |  |  |  | 82 | 29 |  | 4 | 4 |  |  | 8.0 |
|  |  | 5 | LTW |  | 1.61 | 0.58 |  |  |  |  | 12 | 8 |  | 3 | 4 |  |  | 8.1 |
|  |  | 6 | 2% III |  | 1.94 | 1.08 |  |  |  |  | 198 | 45 |  | 4 | 4 |  |  |  |
|  |  | 7 | 1% III |  | 1.35 | 0.61 |  |  |  |  | 71 | 17 |  | 3 | 4 |  |  | 7.8 |
|  |  | 8 | 1% III + TE |  | 1.79 | 0.89 |  |  |  |  | 66 | 22 |  | 3 | 4 |  |  | 8.1 |
| 9-29 | 8<br>Assay No. 4 | 1 | LTW | 16.4 | 1.35 | 0.71 |  |  |  | 60 | <5 | 21 | 84 | 6 | 8 |  | 88 | 8.0 |
|  |  | 2 | 2% III |  | 2.27 | 1.09 |  |  |  | 60 | 158 | 63 | 281 | 4 | 11 |  | 95 | 8.0 |
|  |  | 3 | 1% III |  | 2.29 | 1.12 |  |  |  | 38 | 68 | 35 | 141 | 3 | 15 |  | 92 | 8.0 |
|  |  | 4 | 1% III + TE |  | 2.93 | 1.37 |  |  |  | 98 | 76 | 44 | 218 | 4 | 7 |  | 102 | 8.0 |
|  |  | 5 | LTW |  | 1.50 | 0.62 |  |  |  | 46 | <5 | 23 | 72 | 4 | 12 |  | 86 | 8.0 |
|  |  | 6 | 2% III |  | 2.45 | 1.45 |  |  |  | 46 | 184 | 48 | 278 | 3 | 8 |  | 96 | 8.1 |
|  |  | 7 | 1% III |  | 1.84 | 0.97 |  |  |  | 26 | 76 | 37 | 139 | 3 | 25 |  | 100 | 7.9 |
|  |  | 8 | 1% III + TE |  | 2.80 | 1.27 |  |  |  | 17 | 80 | 35 | 132 | 3 | 20 |  | 91 | 8.0 |
| 9-30 | 8<br>Assay No. 4 | 1 | LTW | 16.1 | 2.71 | 1.03 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 2 | 2% III |  | 4.17 | 1.94 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 3 | 1% III |  | 3.82 | 1.59 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 4 | 1% III + TE |  | 3.60 | 1.60 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 5 | LTW |  | 1.86 | 0.81 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 6 | 2% III |  | 4.02 | 2.30 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 7 | 1% III |  | 2.40 | 1.09 |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 8 | 1% III + TE |  | 3.59 | 1.57 |  |  |  |  |  |  |  |  |  |  |  |  |

TABLE D-1 (Continued)

| Date | Pond Detention Time # days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples | | | | | GP/C Filtered Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suspended Solids mg/l | Volatile Suspended Solids mg/l | Nitrogen as N | | Total Phosphorus | Nitrogen as N | | | | Phosphorus as P | | Fe µg/l | Cond. $(10^{-6})$ mhos | pH |
| | | | | | | | Organic µg/l | $NH_3$ µg/l | | Organic µg/l | $NH_3$ µg/l | $NO_2$-$NO_3$ µg/l | Total µg/l | $PO_4$ µg/l | Total µg/l | | | |
| 10- 1 | 8 Assay No. 4 | 1 | LTW | 16.3 | 1.60 | 0.87 | | | | | 20 | 10 | | 1 | 14 | 9 | | 7.9 |
| | | 2 | 2% III | | 2.15 | 1.03 | | | | | 175 | 44 | | 2 | 10 | 22 | | 7.5 |
| | | 3 | 1% III | | 3.00 | 0.96 | | | | | 86 | 24 | | 2 | 5 | 7 | | 7.9 |
| | | 4 | 1% III + TE | | 2.66 | 1.16 | | | | | 78 | 33 | | 2 | 8 | 3 | | 7.8 |
| | | 5 | LTW | | 1.67 | 0.59 | | | | | 22 | 10 | | 2 | 14 | 1 | | 7.7 |
| | | 6 | 2% III | | 2.63 | 1.40 | | | | | 191 | 36 | | <1 | 9 | 33 | | 7.8 |
| | | 7 | 1% III | | 1.99 | 0.85 | | | | | 86 | 24 | | 2 | 5 | 45 | | 7.7 |
| | | 8 | 1% III + TE | | 3.11 | 1.40 | | | | | 75 | 24 | | <1 | 8 | 33 | | 7.6 |
| 10- 2 | 3 Assay No. 4 | 1 | LTW | 15.1 | 1.73 | | | | | | | | | | | | | |
| | | 2 | 2% III | | 2.06 | | | | | | | | | | | | | |
| | | 3 | 1% III | | 2.75 | | | | | | | | | | | | | |
| | | 4 | 1% III + TE | | 2.24 | | | | | | | | | | | | | |
| | | 5 | LTW | | 1.28 | | | | | | | | | | | | | |
| | | 6 | 2% III | | 3.29 | | | | | | | | | | | | | |
| | | 7 | 1% III | | 1.91 | | | | | | | | | | | | | |
| | | 8 | 1% III + TE | | 3.31 | | | | | | | | | | | | | |
| 10- 3 | 8 Assay No. 4 | 1 | LTW | 14.6 | 1.04 | 0.84 | 99 | 7 | 3 | 77 | 25 | 5 | 107 | 4 | 6 | | | 7.8 |
| | | 2 | 2% III | | 1.65 | | 103 | 215 | 5 | 72 | 292 | 32 | 396 | 3 | 5 | | | 7.7 |
| | | 3 | 1% III | | 1.80 | 0.56 | 170 | 92 | 4 | 44 | 80 | 20 | 144 | 2 | 3 | | | 7.5 |
| | | 4 | 1% III + TE | | 1.94 | 0.05 | 94 | 92 | 4 | 86 | 104 | 28 | 218 | 3 | 3 | | | 7.8 |
| | | 5 | LTW | | 0.91 | 0.44 | 170 | 15 | 3 | 67 | 4 | 2 | 73 | 3 | 5 | | | 7.9 |
| | | 6 | 2% III | | 5.82 | 3.91 | 92 | 134 | 5 | 55 | 196 | 26 | 277 | <1 | 6 | | | 7.6 |
| | | 7 | 1% III | | 1.38 | 0.14 | 82 | 101 | 4 | 96 | 118 | 18 | 232 | 3 | 3 | | | 7.7 |
| | | 8 | 1% III + TE | | 2.46 | 0.94 | 99 | 97 | 4 | 60 | 71 | 18 | 149 | 4 | 4 | | | 7.7 |
| 10- 6 | 5 Assay No. 5 | 1 | LTW | 11.8 | 1.72 | 0.63 | | | | 115 | <5 | 11 | 128 | <1 | 13 | | | 7.3 |
| | | 2 | 2% III | | 2.28 | 0.83 | | | | 60 | 182 | 31 | 273 | 2 | 13 | | | 7.3 |
| | | 3 | 1% III | | 2.70 | 1.00 | | | | 82 | 76 | 24 | 182 | 4 | 4 | | | 7.0 |
| | | 4 | 1% III + TE | | 2.61 | 0.99 | | | | 84 | 53 | 28 | 165 | 2 | 5 | | | 7.7 |
| | | 5 | LTW | | 1.32 | 0.45 | | | | 80 | <5 | 10 | 92 | 3 | 12 | | | 7.1 |
| | | 6 | 2% III | | 2.00 | 0.97 | | | | 36 | 287 | 26 | 349 | 2 | 6 | | | 7.7 |
| | | 7 | 1% III | | 1.04 | 0.68 | | | | | 120 | 24 | | 2 | 4 | | | 7.7 |
| | | 8 | 1% III + TE | | 2.77 | 1.10 | | | | 32 | 94 | 24 | 150 | 2 | 2 | | | 7.5 |
| 10- 8 | 5 Assay No. 5 | 1 | LTW | 11.2 | 2.23 | 0.86 | | | | | 28 | 22 | | 6 | 4 | | | 7.6 |
| | | 2 | 2% III | | 2.40 | 1.02 | | | | | 225 | 34 | | 3 | 3 | | | 7.4 |
| | | 3 | 1% III | | 2.88 | 1.19 | | | | | 118 | 31 | | 7 | 3 | | | 7.5 |
| | | 4 | 1% III + TE | | 2.82 | 1.14 | | | | | 119 | 31 | | 4 | 4 | | | 7.6 |
| | | 5 | LTW | | 2.09 | 1.12 | | | | | 18 | 20 | | 5 | 3 | | | 7.5 |
| | | 6 | 2% III | | 3.16 | 1.93 | | | | | 227 | 30 | | 5 | 3 | | | 8.0 |
| | | 7 | 1% III | | 1.85 | 0.76 | | | | | 114 | 29 | | 4 | 4 | | | 7.6 |
| | | 8 | 1% III + TE | | 4.42 | 1.78 | | | | | 92 | 33 | | 2 | 3 | | | 7.4 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples | | | | | GF/C Filtered Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suspended Solids mg/ℓ | Volatile Suspended Solids mg/ℓ | Nitrogen as N | | Total Phosphorus µg/ℓ | Nitrogen as N | | | | Phosphorus as P | | Fe µg/ℓ | Cond. ($10^{-6}$) mhos | pH |
| | | | | | | | Organic µg/ℓ | $NH_3$ µg/ℓ | | Organic µg/ℓ | $NH_3$ µg/ℓ | $NO_2$-$NO_3$ µg/ℓ | Total µg/ℓ | $PO_4$ µg/ℓ | Total µg/ℓ | | | |
| 10-10 | 5<br>Assay<br>No.<br>5 | 1 | LTW | 10.8 | 0.70 | | | | | | 2 | 15 | | 6 | 10 | | | 8.1 |
| | | 2 | 2% III | | 2.07 | | | | | | 292 | 27 | | 2 | 9 | | | 8.6 |
| | | 3 | 1% III | | 1.90 | | | | | | 172 | 20 | | 2 | 5 | | | 8.1 |
| | | 4 | 1% III + TE | | 2.00 | | | | | | 124 | 29 | | 3 | 6 | | | 7.6 |
| | | 5 | LTW | | 1.07 | | | | | | 4 | 13 | | 3 | 7 | | | 8.0 |
| | | 6 | 2% III | | 3.45 | | | | | | 228 | 21 | | 3 | 15 | | | |
| | | 7 | 1% III | | 1.54 | | | | | | | 18 | | 2 | 18 | | | 8.2 |
| | | 8 | 1% III + TE | | 2.22 | | | | | | 142 | 26 | | 1 | 35 | | | 8.2 |
| 10-13 | 5<br>Assay<br>No.<br>5 | 1 | LTW | 8.0 | 2.37 | 0.76 | | | | 250 | 9 | 18 | 277 | 3 | 7 | | 87 | 7.8 |
| | | 2 | 2% III | | 3.73 | 1.26 | | | | 75 | 244 | 36 | 355 | 2 | 5 | | 86 | 7.9 |
| | | 3 | 1% III | | 4.15 | 1.32 | | | | 82 | 165 | 36 | 283 | 2 | 4 | | 88 | 7.9 |
| | | 4 | 1% III + TE | | 4.59 | 1.41 | | | | 100 | 167 | 42 | 309 | 2 | 5 | | 85 | 8.0 |
| | | 5 | LTW | | 2.77 | 0.82 | | | | 75 | <5 | 27 | 104 | 2 | 4 | | 84 | 7.9 |
| | | 6 | 2% III | | 5.59 | 2.21 | | | | 65 | 287 | 34 | 386 | 1 | 5 | | 87 | 8.2 |
| | | 7 | 1% III | | 3.15 | 0.95 | | | | 75 | 165 | 30 | 270 | 2 | 6 | | 87 | 7.9 |
| | | 8 | 1% III + TE | | 3.88 | 1.41 | | | | 82 | 156 | 40 | 278 | 2 | | | 84 | 8.0 |
| 10-14 | 5<br>Assay<br>No.<br>5 | 1 | LTW | 8.8 | 4.14 | 1.30 | | | | | | | | | | 8 | | |
| | | 2 | 2% III | | 6.07 | 1.98 | | | | | | | | | | 3 | | |
| | | 3 | 1% III | | 5.47 | 1.73 | | | | | | | | | | 33 | | |
| | | 4 | 1% III + TE | | 4.46 | 1.55 | | | | | | | | | | 16 | | |
| | | 5 | LTW | | 3.37 | 1.09 | | | | | | | | | | <1 | | |
| | | 6 | 2% III | | 7.03 | 2.83 | | | | | | | | | | 2 | | |
| | | 7 | 1% III | | 3.72 | 1.29 | | | | | | | | | | 2 | | |
| | | 8 | 1% III + TE | | 6.35 | 4.03 | | | | | | | | | | 16 | | |
| 10-15 | 5<br>Assay<br>No.<br>5 | 1 | LTW | 7.4 | 3.02 | | | | | | 22 | 19 | | 4 | 6 | | | 7.6 |
| | | 2 | 2% III | | 5.83 | | | | | | 292 | 32 | | 4 | 5 | | | 7.8 |
| | | 3 | 1% III | | 5.25 | | | | | | 163 | 36 | | 4 | 6 | | | 7.6 |
| | | 4 | 1% III + TE | | 4.26 | | | | | | 129 | 46 | | 3 | 5 | | | 7.8 |
| | | 5 | LTW | | 2.67 | | | | | | 16 | 26 | | 4 | 5 | | | 7.7 |
| | | 6 | 2% III | | 6.67 | | | | | | 288 | 30 | | 4 | 6 | | | 8.0 |
| | | 7 | 1% III | | 3.61 | | | | | | 168 | 34 | | 3 | 6 | | | 7.8 |
| | | 8 | 1% III + TE | | 4.77 | | | | | | 139 | 41 | | 4 | 6 | | | 7.9 |
| 10-16 | 5<br>Assay<br>No.<br>5 | 1 | LTW | 8.7 | 4.63 | 0.41 | | | | | | | | | | | | |
| | | 2 | 2% III | | 7.87 | 5.39 | | | | | | | | | | | | |
| | | 3 | 1% III | | 7.46 | 5.26 | | | | | | | | | | | | |
| | | 4 | 1% III + TE | | 5.22 | 2.26 | | | | | | | | | | | | |
| | | 5 | LTW | | 3.10 | 0.73 | | | | | | | | | | | | |
| | | 6 | 2% III | | 7.35 | 4.99 | | | | | | | | | | | | |
| | | 7 | 1% III | | 3.84 | 0.76 | | | | | | | | | | | | |
| | | 8 | 1% III + TE | | 4.81 | 2.30 | | | | | | | | | | | | |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples: Suspended Solids mg/l | Unfiltered Samples: Volatile Suspended Solids mg/l | Unfiltered Samples: Nitrogen as N: Organic µg/l | Unfiltered Samples: Nitrogen as N: $NH_3$ µg/l | Unfiltered Samples: Total Phosphorus µg/l | GF/C Filtered Samples: Nitrogen as N: Organic µg/l | GF/C Filtered Samples: Nitrogen as N: $NH_3$ µg/l | GF/C Filtered Samples: Nitrogen as N: $NO_2$-$NO_3$ µg/l | GF/C Filtered Samples: Nitrogen as N: Total µg/l | GF/C Filtered Samples: Phosphorus as P: $PO_4$ µg/l | GF/C Filtered Samples: Phosphorus as P: Total µg/l | GF/C Filtered Samples: Fe µg/l | GF/C Filtered Samples: Cond. ($10^{-6}$) mhos | GF/C Filtered Samples: pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-17 | 5 Assay No. 5 | 1 | LTW | 7.3 | 3.70 | 1.18 | 29 | 22 | 33 | 134 | 42 | 20 | 196 | 2 | 8 | | | 7.7 |
| | | 2 | 2% III | | 6.60 | 2.30 | 146 | 273 | 39 | 130 | 278 | 25 | 433 | <1 | 6 | | | 7.8 |
| | | 3 | 1% III | | 5.17 | 1.85 | 136 | 112 | | 106 | 125 | 30 | 261 | 2 | 6 | | | 7.6 |
| | | 4 | 1% III + TE | | 4.14 | 1.44 | 58 | 136 | 62 | 103 | 137 | 33 | 273 | <1 | 14 | | | 7.8 |
| | | 5 | LTW | | 1.18 | 0.80 | 48 | 38 | 17 | 82 | 24 | 16 | 122 | <1 | 5 | | | 7.8 |
| | | 6 | 2% III | | 6.79 | 2.90 | 82 | 275 | 40 | 34 | 254 | 26 | 314 | 1 | 7 | | | 7.9 |
| | | 7 | 1% III | | 3.26 | 1.27 | 110 | 148 | 31 | 62 | 148 | 22 | 232 | 2 | 12 | | | 7.7 |
| | | 8 | 1% III + TE | | 4.14 | 1.63 | 60 | 148 | 18 | 24 | 127 | 14 | 165 | 1 | 8 | | | 7.6 |
| 10-20 | 3 Assay No. 6 | 1 | LTW | 7.1 | 2.41 | 0.73 | | | | 91 | 34 | 14 | 139 | 4 | 6 | | 86 | 7.8 |
| | | 2 | 2% III | | 7.01 | 2.26 | | | | 79 | 194 | 20 | 293 | 3 | 7 | | 87 | 8.0 |
| | | 3 | 1% III | | 4.16 | 1.47 | | | | 103 | 61 | 22 | 186 | 4 | 7 | | 85 | 8.1 |
| | | 4 | 1% III + TE | | 3.90 | 1.35 | | | | 38 | 76 | 29 | 143 | 6 | 11 | | 87 | 8.1 |
| | | 5 | LTW | | 2.09 | 0.70 | | | | 67 | 46 | 13 | 126 | 3 | 7 | | 83 | 8.0 |
| | | 6 | 2% III | | 6.86 | 2.75 | | | | 15 | 225 | 18 | 258 | 4 | 6 | | 86 | 8.2 |
| | | 7 | 1% III | | 2.90 | 0.96 | | | | 67 | 100 | 20 | 187 | 3 | 8 | | 88 | 8.1 |
| | | 8 | 1% III + TE | | 3.34 | 1.23 | | | | 29 | 82 | 26 | 137 | 3 | 5 | | 86 | 8.0 |
| 10-22 | 3 Assay No. 6 | 1 | LTW | 10.5 | 3.76 | | | | | | <1 | 6 | | 4 | 5 | | | 7.8 |
| | | 2 | 2% III | | 9.77 | | | | | | 177 | 9 | | 3 | 5 | | | 8.2 |
| | | 3 | 1% III | | 5.97 | | | | | | 103 | 14 | | 3 | 3 | | | 8.2 |
| | | 4 | 1% III + TE | | 4.80 | | | | | | 89 | 17 | | 3 | 3 | | | 8.3 |
| | | 5 | LTW | | 1.75 | | | | | | <1 | 12 | | 3 | 6 | | | 8.2 |
| | | 6 | 2% III | | 8.76 | | | | | | 196 | 8 | | 2 | 5 | | | 8.4 |
| | | 7 | 1% III | | 3.13 | | | | | | 105 | 10 | | 3 | 5 | | | 8.3 |
| | | 8 | 1% III + TE | | 3.32 | | | | | | 89 | 15 | | 3 | 5 | | | 8.1 |
| 10-24 | 3 Assay No. 6 | 1 | LTW | 11.2 | 1.52 | 0.62 | | | | | 8 | 5 | | 2 | 6 | | | 8.1 |
| | | 2 | 2% III | | 8.82 | 2.94 | | | | | 220 | 10 | | 2 | 8 | | | 8.1 |
| | | 3 | 1% III | | 5.47 | 1.77 | | | | | 182 | 14 | | 3 | 5 | | | 8.2 |
| | | 4 | 1% III + TE | | 4.46 | 1.32 | | | | | 153 | 22 | | 4 | 5 | | | 8.1 |
| | | 5 | LTW | | 1.99 | 0.59 | | | | | 10 | 6 | | 4 | 7 | | | 8.2 |
| | | 6 | 2% III | | 9.86 | 3.74 | | | | | 306 | 12 | | 5 | 6 | | | 8.3 |
| | | 7 | 1% III | | 2.99 | 0.96 | | | | | 191 | 12 | | 4 | 7 | | | 8.2 |
| | | 8 | 1% III + TE | | 3.59 | 1.21 | | | | | 135 | 21 | | 10 | 12 | | | 8.2 |
| 10-27 | 3 Assay No. 6 | 1 | LTW | 9.5 | 4.75 | 1.07 | | | | 10 | <1 | 10 | 20 | 3 | 4 | | 89 | 7.9 |
| | | 2 | 2% III | | 14.61 | 4.52 | | | | 82 | 177 | 13 | 272 | 3 | 6 | | 92 | 8.3 |
| | | 3 | 1% III | | 8.76 | 2.47 | | | | 10 | 184 | 20 | 214 | 3 | 5 | | 91 | 8.2 |
| | | 4 | 1% III + TE | | 7.03 | 2.00 | | | | 31 | 175 | 25 | 231 | 2 | 5 | | 91 | 8.2 |
| | | 5 | LTW | | 3.24 | 1.09 | | | | 70 | <5 | 9 | 82 | 2 | 6 | | 86 | 8.1 |
| | | 6 | 2% III | | 15.17 | 5.60 | | | | 70 | 201 | 17 | 288 | 2 | 6 | | 96 | 8.4 |
| | | 7 | 1% III | | 6.08 | 1.77 | | | | 48 | 160 | 13 | 221 | 2 | 4 | | 91 | 8.2 |
| | | 8 | 1% III + TE | | 6.44 | 2.17 | | | | 39 | 172 | 20 | 231 | 4 | 6 | | 91 | 8.2 |

TABLE D-1 (Continued)

| Date | Pond Detention Time θ days | Pond No. | Influent Description | Temperature °C | Unfiltered Samples | | | | | GF/C Filtered Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suspended Solids | Volatile Suspended Solids | Nitrogen as N | | Total Phosphorus | Nitrogen as N | | | | Phosphorus as P | | Fe | Cond. ($10^{-6}$) | pH |
| | | | | | mg/ℓ | mg/ℓ | Organic µg/ℓ | $NH_3$ µg/ℓ | µg/ℓ | Organic µg/ℓ | $NH_3$ µg/ℓ | $NO_2$-$NO_3$ µg/ℓ | Total µg/ℓ | $PO_4$ µg/ℓ | Total µg/ℓ | µg/ℓ | mhos | |
| 10-28 | 3 Assay No. 6 | 1 | LTW | 9.3 | 1.70 | 0.58 | | | | | | | | | | | | |
| | | 2 | 2% III | | 11.96 | 4.20 | | | | | | | | | | | | |
| | | 3 | 1% III | | 4.87 | 1.83 | | | | | | | | | | | | |
| | | 4 | 1% III + TE | | 5.33 | 1.76 | | | | | | | | | | | | |
| | | 5 | LTW | | 2.30 | 0.82 | | | | | | | | | | | | |
| | | 6 | 2% III | | 13.75 | 5.65 | | | | | | | | | | | | |
| | | 7 | 1% III | | 4.71 | 1.71 | | | | | | | | | | | | |
| | | 8 | 1% III + TE | | 5.54 | 2.03 | | | | | | | | | | | | |
| 10-29 | 3 Assay No. 6 | 1 | LTW | 9.2 | 3.43 | 1.00 | | | | | 38 | 26 | | 3 | | | | 7.9 |
| | | 2 | 2% III | | 10.27 | 3.54 | | | | | 172 | 18 | | 2 | | | | 8.1 |
| | | 3 | 1% III | | 4.77 | 1.43 | | | | | 96 | 26 | | 3 | | | | 8.0 |
| | | 4 | 1% III + TE | | 5.13 | 1.79 | | | | | 156 | 29 | | 2 | | | | 7.9 |
| | | 5 | LTW | | 1.63 | 0.59 | | | | | 39 | 19 | | 3 | | | | 7.8 |
| | | 6 | 2% III | | 10.67 | 4.38 | | | | | 179 | 22 | | 2 | | | | 8.2 |
| | | 7 | 1% III | | 5.22 | 1.86 | | | | | 114 | 22 | | 2 | | | | 7.8 |
| | | 8 | 1% III + TE | | 5.55 | 2.21 | | | | | 136 | 26 | | 1 | | | | 8.0 |
| 10-30 | 3 Assay No. 6 | 1 | LTW | 8.4 | 4.25 | | | | | | | | | | | | | |
| | | 2 | 2% III | | 14.05 | | | | | | | | | | | | | |
| | | 3 | 1% III | | 7.72 | | | | | | | | | | | | | |
| | | 4 | 1% III + TE | | 7.30 | | | | | | | | | | | | | |
| | | 5 | LTW | | 3.50 | | | | | | | | | | | | | |
| | | 6 | 2% III | | 14.82 | | | | | | | | | | | | | |
| | | 7 | 1% III | | 6.32 | | | | | | | | | | | | | |
| | | 8 | 1% III + TE | | 6.94 | | | | | | | | | | | | | |
| 10-31 | 3 Assay No. 6 | 1 | LTW | 9.4 | 3.95 | 1.08 | 32 | 5 | 10 | 29 | 4 | 17 | 50 | 6 | 7 | | | 8.1 |
| | | 2 | 2% III | | 11.40 | 3.73 | 250 | 208 | 10 | 50 | 242 | 20 | 312 | 2 | 6 | | | 8.1 |
| | | 3 | 1% III | | 5.91 | 1.63 | 60 | 108 | 9 | 38 | 126 | 21 | 185 | 2 | 10 | | | 8.0 |
| | | 4 | 1% III + TE | | 6.36 | 1.84 | 86 | 275 | 14 | 40 | 127 | 32 | 199 | 3 | 6 | | | 8.2 |
| | | 5 | LTW | | 2.69 | 0.63 | 46 | 17 | 6 | 16 | 2 | 19 | 37 | 2 | 4 | | | 8.0 |
| | | 6 | 2% III | | 12.57 | 4.67 | 280 | 258 | 11 | 65 | 258 | 11 | 334 | 2 | 4 | | | 8.4 |
| | | 7 | 1% III | | 5.20 | 1.65 | 74 | 153 | 10 | 38 | 127 | 28 | 193 | 2 | 4 | | | 8.0 |
| | | 8 | 1% III + TE | | 5.54 | 1.90 | 134 | 172 | 9 | 32 | 108 | 28 | 168 | 2 | 4 | | | 8.2 |

[a] LTW – Lake Tahoe Water.
0.1% II – 0.1% secondary effluent from South Tahoe Public Utility District's (STPUD) Waste Treatment Plant and 99.9% LTW.
1% II – 1.0% secondary effluent from STPUD Waste Treatment Plant and 99.0% LTW.
1% S-II – 1.0% simulated (chemically) secondary effluent and 99.0% LTW (see Table A-1).

[b] LTW – Lake Tahoe Water.
2% III – 2% tertiary effluent from STPUD Waste Treatment Plant + 98% LTW (tertiary effluent is collected before chlorination).
1% III – 1% tertiary effluent from STPUD Waste Treatment Plant + 99% LTW.
1% III + TE – 1% tertiary effluent from STPUD Waste Treatment Plant + trace elements (see Table A-1) + 99% LTW.

[c] Rate of influent Lake Tahoe Water to Pilot Pond 7 was found to be approximately 3-1/2 times the designed rate (for up to possibley 4 days), this, creating a "washout" effect.

TABLE D-2

PILOT POND BIOMASS MEASUREMENTS[a] (FLASK ASSAY)

| Date of Sampling | Sample Type[e] | Concentration (% of Sample) % | Pond No. | Pond Detention Time θ days | Detention Time θ<br>1 day<br>Counts[b] cell no./mm³ | 3 day<br>Counts[b] cell no./mm³ | 5 day<br>Counts[b] cell no./mm³ | 5 day<br>Suspended[c] Solids mg/ℓ | 5 day<br>pH[d] |
|---|---|---|---|---|---|---|---|---|---|
| 8- 6 | LTW[e] | 100 | 1 | 8 Assay No. 1 | 85.8 | 108.9 | 115.1 | 2.03 | 7.8 |
| | 0.1% II | 100 | 2 | | 91.7 | 124.8 | 125.4 | 3.03 | 7.9 |
| | 1% II | 100 | 3 | | 88.2 | 143.4 | 174.0 | 3.51 | 7.9 |
| | 1% S-II | 100 | 4 | | 87.5 | 243.0 | 285.2 | 4.21 | 8.0 |
| | LTW | 100 | 5 | | 81.9 | 108.6 | 116.0 | 2.18 | 7.9 |
| | 0.1% II | 100 | 6 | | 85.1 | 104.8 | 79.2 | 2.42 | 8.0 |
| | 1% II | 100 | 7 | | 89.8 | 209.4 | 248.7 | 4.42 | 8.1 |
| | 1% S-II | 100 | 8 | | 92.2 | 227.7 | 246.4 | 4.92 | 8.0 |
| | SLTW | 100 | Header | | 86.5 | 114.9 | 92.4 | 2.39 | 8.0 |
| 8-20 | LTW | 100 | 1 | 5 Assay No. 2 | 89.7 | 8[illegible].4 | 99.1 | | |
| | 0.1% II | 100 | 2 | | 104.1 | 90.1 | 95.4 | | |
| | 1% II | 100 | 3 | | 76.1 | 126.6 | 142.4 | | |
| | 1% S-II | 100 | 4 | | 79.2 | 164.2 | 189.6 | | |
| | LTW | 100 | 5 | | 74.6 | 89.6 | 96.2 | | |
| | 0.1% II | 100 | 6 | | 78.5 | 82.2 | 93.5 | | |
| | 1% II | 100 | 7 | | 94.4 | 95.4 | 104.7 | | |
| | 1% S-II | 100 | 8 | | 82.1 | 99.2 | 115.8 | | |
| | SLTW | 100 | Header | | 74.7 | 88.9 | 117.7 | | |
| 9- 2 | LTW | 100 | 1 | 3 Assay No. 1 | 49.8 | 114.2 | 179.0 | 1.61 | f |
| | 0.1% II | 100 | 2 | | 54.3 | 122.0 | 180.2 | 1.69 | |
| | 1% II | 100 | 3 | | 76.6 | 247.2 | 320.1 | 1.86 | |
| | 1% S-II | 100 | 4 | | 61.3 | 142.3 | 220.1 | 1.51 | |
| | LTW | 100 | 5 | | 54.3 | 130.9 | 167.3 | 2.18 | |
| | 0.1% II | 100 | 6 | | 53.2 | 96.7 | 117.1 | 3.66 | |
| | 1% II | 100 | 7 | | 127.6 | 363.0 | 470.5 | 2.20 | |
| | 1% S-II | 100 | 8 | | 127.0 | 352.3 | 467.6 | | |
| | SLTW | 100 | Header | | 50.9 | 166.2 | 221.6 | 1.72 | |
| 10- 1[g] | LTW[h] | 100 | 1 | 8 Assay No. 4 | 72.3 | 59.5 | 90.9 | 3.88 | 7.9 |
| | 2% III | 100 | 2 | | 58.0 | 57.9 | 119.1 | 1.55 | 7.9 |
| | 1% III | 100 | 3 | | 59.6 | 57.0 | 96.2 | 1.32 | 7.8 |
| | 1% III + TE | 100 | 4 | | 58.2 | 76.8 | 100.5 | 1.84 | 7.9 |
| | LTW | 100 | 5 | | 71.3 | 157.3 | 186.4 | 2.25 | 7.9 |
| | 2% III | 100 | 6 | | 56.2 | 51.0 | 104.5 | 1.50 | 7.9 |
| | 1% III | 100 | 7 | | 57.2 | 70.6 | 93.3 | 4.74 | 7.9 |
| | 1% III + TE | 100 | 8 | | 60.2 | 119.5 | 182.2 | 2.07 | 7.9 |
| | SLTW | 100 | Header | | [illegible]9.4 | 105.3 | 146.9 | 3.41 | 7.9 |
| 10-14[i] | LTW | 100 | 1 | 5 Assay No. 5 | 52.6 | 156.4 | 210.6 | 1.85 | 7.8 |
| | 2% III | 100 | 2 | | 49.0 | 117.5 | 192.7 | 1.61 | 7.7 |
| | 1% III | 100 | 3 | | 48.3 | 150.6 | 207.5 | 1.31 | 7.8 |
| | 1% III + TE | 100 | 4 | | 43.9 | 131.8 | 204.4 | 1.67 | 7.7 |
| | LTW | 100 | 5 | | 59.6 | 144.9 | 207.7 | 1.49 | 7.7 |
| | 2% III | 100 | 6 | | 54.6 | 114.7 | 152.6 | 1.26 | 7.7 |
| | 1% III | 100 | 7 | | 69.2 | 171.5 | 252.9 | 1.66 | 7.7 |
| | 1% III + TE | 100 | 8 | | 59.2 | 140.6 | 205.4 | 1.26 | 7.7 |
| | SLTW | 100 | Header | | 116.9 | 248.8 | 312.0 | 2.29 | 7.7 |
| 10-27 | LTW | 100 | 1 | 3 Assay No. 6 | 145.0 | 227.0 | 252.5 | 2.29 | 7.7 |
| | 2% III | 100 | 2 | | 138.7 | 203.1 | 224.4 | 3.10 | 7.9 |
| | 1% III | 100 | 3 | | 135.8 | 209.8 | 693.8 | 3.76 | 7.7 |
| | 1% III + TE | 100 | 4 | | 123.8 | 135.7 | 170.2 | 2.57 | 7.7 |
| | LTW | 100 | 5 | | 153.3 | 213.6 | 215.4 | 2.02 | 7.6 |
| | 2% III | 100 | 6 | | 153.2 | 183.5 | 643.0 | 2.52 | 7.7 |
| | 1% III | 100 | 7 | | 126.0 | 189.4 | 218.0 | 2.33 | 7.4 |
| | 1% III + TE | 100 | 8 | | 93.1 | 141.7 | 174.6 | 2.50 | 7.4 |
| | SLTW | 100 | Header | | 120.1 | 138.8 | 176.2 | 2.15 | 7.4 |

[a] Samples passed through a 0.45 μ Millipore filter and then inoculated with a culture of Selenastrum capricornutum at a concentration of 50 cells/mm³.

[b] Counts enumerated by use of a "Coulter Counter" on five replicate samples.

[c] Analyses performed by GF/C filters.

[d] Analyzed on the culture after it passed through the GF/C filter.

[e] LTW - Lake Tahoe Water.
0.1% II - 0.1% secondary effluent from South Tahoe Public Utility District's (STPUD) Waste Treatment Plant and 99.9% LTW.
1% II - 1% secondary effluent from STPUD Waste Treatment Plant and 99% LTW.
1% S-II - 1% simulated (chemically) secondary effluent and 99% LTW (see Table A-1).
SLTW - Shore-Lake Tahoe Water, sampled at the header before it enters the pilot pond.

[f] pH meter inoperative.

[g] Culture test cell organism was contaminated with a "Chlorella" type organism. Only a small percentage of S. capricornutum was observed.

[h] LTW - Lake Tahoe Water.
2% III - 2 % tertiary effluent from STPUD Waste Treatment Plant + 98% LTW (tertiary effluent is collected before chlorination).
1% III - 1% tertiary effluent from STPUD Waste Treatment Plant + 99% LTW.
1% III + TE - 1% tertiary effluent from STPUD Waste Treatment Plant + trace elements (see Table A-1) + 99% LTW.

[i] New "pure" culture of S. capricornutum.

# APPENDIX E

TABLE E-1

CREEK WATER ANALYSES

| Date | Creek Name | Unfiltered Samples | | | 0.45 μ Millipore Filtered Samples | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nitrogen as N | | | | | Phosphorus as P | | | | | | | |
| | | Susp. Solids mg/ℓ | Vol. Susp. Solids mg/ℓ | COD mg/ℓ | Organic μg/ℓ | $NH_3$ μg/ℓ | $NO_2$ μg/ℓ | $NO_3$ μg/ℓ | Total μg/ℓ | $PO_4$ μg/ℓ | Total μg/ℓ | Ca mg/ℓ | Cl mg/ℓ | Fe μg/ℓ | pH | Alk. as $CaCO_3$ mg/ℓ | Cond. $10^{-6}$ mhos |
| 1969 | | | | | | | | | | | | | | | | | |
| 1- 3 | Ward[a] | - | - | - | 20 | 25 | 6 | 29 | 80 | 5 | 9 | - | 0.2 | <1 | 7.4 | 27.4 | 40 |
| | Incline | - | - | - | 110 | 55 | 8 | 51 | 284 | 4 | 10 | - | 0.8 | 168 | 7.4 | 31.9 | 39 |
| | Tr. Tr.[b] | - | - | - | 155 | 95 | 8 | 54 | 312 | 37 | 44 | - | 2.9 | 125 | 7.3 | 25.1 | 44 |
| 2- 4 | Ward | - | - | <1 | 33 | 9 | 5 | 26 | 73 | 8 | 12 | - | 0.5 | 15 | 7.6 | 26.6 | 44 |
| | Incline | - | - | <1 | 310 | 690 | 73 | 427 | 1460 | 900 | 980 | - | 6.8 | 154 | 7.8 | 35.3 | 95 |
| | Tr. Tr.[b] | - | - | 1 | 55 | 47 | 9 | 79 | 190 | 15 | 40 | - | 3.9 | 170 | 7.3 | 22.2 | 47 |
| 3- 4 | Ward | - | - | <1 | 82 | 8 | <1 | 13 | 104 | 8 | 18 | 7.5 | 0.3 | <1 | 7.9 | 27.4 | 46 |
| | Incline | - | - | <1 | 125 | 31 | <1 | 78 | 234 | 24 | 33 | 8.4 | 1.8 | 140 | 8.0 | 35.8 | 70 |
| | Tr. Tr.[b] | - | - | <1 | 135 | 31 | 3 | 111 | 280 | 10 | 23 | 8.4 | 4.8 | 154 | 7.9 | 33.1 | 70 |
| 4- 1 | Ward | - | - | <1 | 30 | 70 | 7 | 39 | 146 | 3 | 4 | 7.5 | 0.4 | <1 | 7.4 | 23.6 | 43 |
| | Incline | - | - | <1 | 400 | 520 | 35 | 277 | 1232 | 148 | 154 | 8.4 | 3.8 | 106 | 7.4 | 27.4 | 45 |
| | Tr. Tr. | - | - | <1 | 150 | 154 | 11 | 31 | 326 | 4 | 7 | 6.5 | 3.2 | 76 | 7.2 | 15.4 | 46 |
| 5- 6 | Ward | - | - | 7[c] | 75 | <5 | 3 | 21 | 102 | 7 | 8 | 6.2 | 1.0 | - | 7.1 | 21.0 | 39 |
| | Incline | - | - | 16[c] | 140 | 31 | 4 | 74 | 249 | 22 | 28 | 5.2 | 1.2 | - | 7.2 | 20.1 | 36 |
| | Tr. Tr. | - | - | 2[c] | 135 | 10 | 4 | 34 | 183 | 5 | 9 | 3.8 | 2.9 | - | 7.2 | 14.2 | 33 |
| 6- 4 | Ward | - | - | 35[c] | 105 | <5 | 4 | 20 | 132 | 3 | 17 | 3.6 | 0.2 | 5 | 7.2 | 15.0 | 33 |
| | Incline | - | - | 78[c] | 33 | 30 | 4 | 29 | 96 | 9 | 25 | 3.3 | 0.4 | 47 | 7.2 | 17.6 | 37 |
| | Tr. Tr. | - | - | 91[c] | 112 | 41 | 4 | 5 | 162 | 2 | 11 | 2.0 | 0.8 | 20 | 6.9 | 9.0 | 24 |
| 7- 1 | Ward | - | - | - | 24 | 9 | 5 | 10 | 48 | 3 | 35 | 5.0 | 0.4 | <1 | 7.0 | 17.7 | 41 |
| | Incline | - | - | 7 | 24 | <5 | 5 | 23 | 54 | 15 | 26 | 5.0 | 0.6 | 73 | 7.0 | 20.2 | 41 |
| | Tr. Tr. | - | - | 28 | 50 | 14 | 3 | 11 | 78 | 3 | 13 | 2.6 | 0.9 | 8 | 6.8 | 11.9 | 30 |
| 8-5 | Ward | - | - | <1 | 115 | 30 | 2 | 7 | 154 | 9 | 24 | 5.8 | 0.4 | <1 | 7.4 | 23.0 | 44 |
| | Incline | - | - | 13 | 182 | 19 | 3 | 97 | 301 | 26 | 43 | 5.0 | 0.6 | 54 | 7.4 | 24.3 | 50 |
| | Tr. Tr.[d] | - | - | 5 | 261 | 45 | 2 | 40 | 348 | 9 | 22 | 12.6 | 1.8 | 14 | 7.2 | 18.1 | 43 |
| 8- 8 | Incline A[e] | 1.62 | 0.85 | 3 | 231 | 73 | 3 | 41 | 350 | 6 | 35 | 4.9 | 0.8 | 103 | 7.5 | 19.5 | 39 |
| | Incline B | 72.05 | 14.34 | 4 | 181 | 64 | 3 | 43 | 291 | 16 | 48 | 9.9 | 0.6 | 47 | 7.8 | 43.1 | 70 |
| | Incline C | 46.85 | 9.60 | 4 | 184 | 79 | 3 | 23 | 289 | 21 | 74 | 5.9 | 0.4 | 140 | 7.6 | 27.8 | 44 |
| 9-10 | Ward | 0.68 | 0.64 | - | 60 | 36 | 2 | 18 | 116 | 12 | 16 | 6.6 | 0.3 | <1 | 7.8 | 35.2 | 54 |
| | Incline | 34.04 | 10.23 | - | 256 | 162 | 3 | 181 | 602 | 15 | 73 | 4.9 | 1.8 | 170 | 7.7 | 30.0 | 58 |
| | Tr. Tr. | 2.22 | 1.50 | - | 856 | 59 | 3 | 51 | 969 | 4 | 140 | 4.4 | 3.2 | 48 | 7.5 | 27.0 | 48 |
| 10- 2 | Ward | 0.42 | 0.42 | <1 | 146 | 19 | 2 | 7 | 174 | 14 | 22 | 8.5 | 1.6 | 5 | 7.9 | 37.6 | 75 |
| | Incline | 21.85 | 4.50 | <1 | 548 | 37 | 3 | 21 | 609 | 7 | 15 | 6.3 | 1.2 | 137 | 7.7 | 30.9 | 61 |
| | Tr. Tr. | 2.04 | 1.26 | 11 | 222 | 10 | 3 | 61 | 296 | 5 | 7 | 6.5 | 2.9 | 70 | 7.8 | 29.6 | 70 |
| 11- 4 | Ward | 0.66 | 0.53 | - | 149 | 30 | 3 | 17 | 199 | 24 | 29 | 7.8 | 0.8 | 30 | 7.6 | 34.4 | 70 |
| | Incline | 7.55 | 1.87 | - | 237 | 13 | 1 | 17 | 268 | 12 | 22 | 6.6 | 1.0 | 177 | 7.5 | 31.2 | 62 |
| | Tr. Tr. | 2.66 | 2.11 | - | 252 | 21 | 4 | 58 | 335 | 6 | 17 | 7.0 | 2.3 | 77 | 7.5 | 30.1 | 66 |
| 12- 4 | Ward | - | - | 15 | 179 | 14 | <1 | 4 | 197 | 13 | 18 | 8.5 | 0.5 | 2 | 7.5 | - | 63 |
| | Incline | 18.06 | 5.13 | 10 | 118 | 40 | <1 | 25 | 184 | 13 | 18 | 5.8 | 0.4 | 126 | 7.0 | - | 50 |
| | Tr. Tr. | 13.40 | 4.79 | <1 | 208 | 60 | 2 | 93 | 365 | 7 | 13 | 5.5 | 3.2 | 45 | 6.9 | - | 57 |

[a] Sampling point location:
Ward – Ward Creek – upstream side of bridge on Highway 89.
Incline – Incline Creek – approximately 150 ft upstream from bridge on Lakeshore Boulevard (old Highway 28).
Tr. Tr. – Upper Truckee-Trout River – downstream from the confluence of the Upper Truckee River and Trout Creek across from the Marina of the Tahoe Keys Development.

[b] Marina frozen.

[c] Results questionable due to equipment malfunctioning.

[d] New earth movement operations opened up a new channel for the Marina and also constructed a dike seperating the Marina from the sampling point. Therefore, the samples now not influenced by the Marina.

[e] Sampling point location:
A – above Incline Village in an undeveloped and undisturbed area.
B – below an area under construction at the time the sample was collected.
C – regular sampling point.

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